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THE UNITED STATES TRIPLE-SCREW PROTECTED CRUISER *COLUMBIA.*

BY PASSED ASSISTANT ENGINEER THOMAS F. CARTER, U. S. NAVY.

The distinguishing feature of this vessel, and the one that has made her an object of special interest from her design to the completion of the official contract trial, is the application of three screws for propulsion. This radical departure from usual designs calls for more than a passing notice, and I shall therefore introduce the detailed description of the vessel by a brief consideration of the subject of multiple screws.

It would doubtless be of considerable interest, at least historically, to trace exhaustively the use of multiple screws from the first application, but this would demand facilities in the way of technical libraries and leisure which have not been at my command. It may be remarked, however, that during our late Civil War (1861–1865) a class of very shallow-draught vessels, known as "tin-clads," was built for service on the Mississippi, and these were fitted with four screws. Here the *raison d'être* of the multiple screws was undoubtedly the impossibility of getting

adequate propelling surface in a single screw wholly immersed. Twin screws were used in some of the larger monitors, those with double turrets, during the same period, and doubtless partly for the reason already stated and for increased facility in manœuvring. The obvious advantage of twin screws for manœuvring purposes led to their general adoption for large war vessels, even during the transition period from sail to steam, when the attempt was made to have full sail as well as steam power, and in recent years they have been generally fitted, even in vessels as small as 800 tons, and in torpedo boats of all sizes.

About 1874 the Russian circular monitors, known as Popoffkas (after the inventor, Admiral Popoff) were built, having six screws. The first two of these vessels, the *Novgorod* and the *Admiral Popoff*, were respectively 101 feet and 121 feet in diameter, with draughts of 13 feet 2 inches and 13 feet, and displacements of 2,490 and 3,550 tons. The nominal horse power of the engines was 480 and 640. The *Novgorod* made a speed of 8.5 knots on 2,270 I.H.P., a very poor result compared with the performance of vessels of ordinary form. The descriptions of this type of vessel which have come under my notice are confined to the hull design, so that I am not able to state the reasons for the six screws. It would appear, however, that, of the three screws on each side of the fore-and-aft diameter, the central one was of greater diameter than the others, and in fact extended below the flat bottom, so that it was not to be used in shallow water. Probably the large number of screws, the outer ones coming to within a third of the radius from the sides, was to secure some approach to decent steering, and it may be that the large screws only were to be used for cruising at low speeds in deep water. If this surmise is correct, we have the germ of one of the objects of the modern triple screws.

The "Scientific American" supplement for January 15, 1876, p. 44, gives an account, with illustrations, of a steam canal boat called the *Wagtail*, fitted with four screws, which had been used in England with satisfactory results. The object in this case is distinctly stated to be the securing of adequate propelling area on a very limited draught of water, 2 feet 9 inches. The boat was in reality

a box, as the cross section for about two-thirds the length was absolutely square, while the bow and stern were formed by cutting off the corners of the parallelopiped. No data are given of the performance, which in any case could not be expected to be of much service to us.

In 1880 the Russian Imperial yacht *Livadia* was built with three screws. The immersed portion of this vessel has been called "turbot shaped," and it seems to be a modification of the Popoffkas. The dimensions were 246 feet long, 153 feet beam, 7 feet mean draught; displacement, 4,400 tons. On trial a speed of 15.77 knots was secured with 12,354 I.H.P. This also is a very poor performance, as our *Baltimore*, *Philadelphia* or *San Francisco* would exceed 20 knots with that power. It might seem at first thought that the triple screws were used in this case on account of shallow draught, but the screws fitted had a diameter of about 16 feet, the shafts being lowered so that they came just above the inner skin. The probability is that three screws were used partly for facility in manœuvring, and partly because, with the low piston speeds and steam pressures at that time, twin screws would have caused the engines to be inconveniently large. The *Livadia* was a failure, so that there are no data as to the success of the triple screws apart from the trial trip.

We now come to more recent dates, and to the application of triple screws to hulls of very good design. An excellent résumé of the French experiments with triple screws was given by Chief Engineer C. W. Rae, U. S. Navy, in the Naval Intelligence Annual for 1889, and is here reproduced:

TRIPLE SCREWS.

"In 1884 and 1885 the French Government conducted a series of trials with a steam launch called the *Carpe*, built for the purpose and fitted with three screws.

"In 1886 M. Marchal read a paper before the Institution of Naval Architects based upon the results of the *Carpe's* performances, from which we abstract the following:

"'The object of increasing the number of propellers is to obtain certain fighting qualities, but not to realize an increased efficiency.'

"The principal object was to decide which of two arrangements of the lateral screws gave the better result, especially as regards mutual interference; one position, in the same transverse plane as the central screw and the other situated more in advance, the shafts being also brought closer together, so as to avoid all projection of the propellers beyond the lines of the hull.

"The experiments were divided into series, according to the positions of the lateral screws.

"The first series comprised all those trials in which the extreme screws were in the same transverse plane as the central screw.

"In this series the following propellers were tried successively:

"Three screws of 44 cm. diameter, the ratio of pitch to diameter being 1.25.

"Three screws of the same diameter, the ratio of pitch to diameter being 1.55.

"Two large screws mounted on the lateral shafts, having, like the first, the number 1.25 as ratio of pitch to diameter, but having a diameter of 54 cm., so that the sum of the areas of the surface described by the extremities of their blades equaled the three corresponding areas of the smaller screws. For the sake of simplicity, we will say that the propulsive surface was the same in each case.

"Finally, the small lateral screws were put back by themselves, and the first group of experiments tried over again, the two pitches being tested turn about. This last formed a series complementary to the first.

"'Contrary to what might have been expected, the greatest pitch, although its ratio to diameter was very high, turned out to be the most favorable to speed. This result was due to the fact that the screws mutually influenced each other at high speeds in consequence of their proximity, and this influence, which was scarcely peceptible at about 500 revolutions, was very marked with the screws of small pitch when driven at about 150 revolutions more than the above number. The proof of this was

forthcoming when the central screw was suppressed in the experiments complementary to the first series. In this case the propellers were more completely independent, and the screw of smaller pitch had the advantage. It was also ascertained that with this pitch an increase of speed was gained when the central screw was suppressed. Further experiment confirmed this result.

"'On the other hand, the best of the two sets of three screws above mentioned hardly attained the efficiency of the two large screws. This fact ought to occasion no surprise, for the substitution of the double for the triple system of screws only implied that a propulsive surface, equal in the two cases, was in the latter instance more completely separated from the hull.'

"The intermediary series of experiments consisted of trials with three screws, so arranged that the lateral propellers were mounted in advance of their supports, and 33 cm. in front of the position assigned the central one.

"'The propellers being then at a greater distance from one another, the effect of an exaggerated speed of rotation made itself less felt, as indeed might have been expected, and the advantage remained with the screws of small pitch.

"'It may then be concluded that, whenever the independence of the propellers is sufficiently provided for, the pitch whose ratio to diameter is 1.25, should be preferred to a more rapid one, as well for systems of three as of two screws.'

"In the second series of experiments the lateral shafts were brought nearer together by 65 mm., while still remaining 33 cm. in advance of the central screw, so that they were completely covered by the exterior contour of the hull. The supports of the shafts were then placed in front of the screws in the usual way.

"'The results differ but little from those obtained in the intermediate series. However, in analyzing the results, it is to be remarked that at low speeds the latter position is less advantageous, which tends to prove that in this case it is the injurious effect of the proximity of the hull which affects the result. At high speed, on the contrary, the latter arrangement proved to be supe-

rior, which result must be attributed to the better relative position of the supports. It is easy to understand that this influence predominates at high speed, since the resistances to progression increase at a much more rapid rate than the speed.

"'If we reflect that rudders have much less influence when placed before the screw than when behind it, it will be understood that a body in the neighborhood of the screw is especially prejudicial when it acts as an obstacle to the water which the latter projects.'

"M. Marchal then describes an experiment he made with a small screw revolving in air, and its effect upon the flame of a lighted candle when held at different points within its influence.

"He found that 'the screw draws air from all points situated in front of a transverse plane passing through the extremity of its blades, and even from a little behind this plane. It then projects this air in a truncated cone, or, more correctly, a sort of truncated pear, the small base of which is a circle equal to the diameter of the screw, the generating line being inclined at the outside at an angle of 30 degrees at the start. Properly speaking, the surface generated by this line is a zone of unstable equilibrium, within which the flame is repelled, and on the outside of which the tendency to attraction is made manifest.'

"'It is important to remark that in this case the screw turns in a fixed position, and if we had to do with a vessel in motion the truncated cone would be drawn out so as to approach the shape of a cylinder. I had the opportunity of verifying this induction in a voyage in the tropics during nights when the sea was phosphorescent. The mass of water thrown back by the screw appeared to be inclosed in a cylinder of the same diameter as the propeller, and had the appearance of a sort of luminous spiral fagot, which I could not better describe than by comparing it to a cable of very slow pitch which continually untwisted itself in proportion as its length increased.

"'From this observation it results that a bracket placed in front of the screw allows the fluid to reach the latter from a multitude of points, while if placed behind it intercepts a slice of a truncated cone proportional to its own section.

"'The facts also show why there is an object in putting the screws solely behind the vessel, and not simultaneously in front and behind.

* * * * * * *

"'In short, one may conclude from this experiment that if the three screws interfere with each other at great speeds, when they are placed in the same transverse plane, it is not because they send water to each other in consequence of the phenomenon designated by the name *dispersion*, but because they dispute with each other for the possession of the water which they draw upon.'

"M. Marchal sums up the result of the experiments as follows:

"'With vessels of the form of the *Carpe* three screws are, from the point of view of speed, very nearly equivalent to two screws of the same propulsive surface, and immersed to the same depth, when the most favorable position is chosen for each system.

"'Twin screws, when under the above-mentioned conditions of surface and immersion, occupy in all cases positions which are disadvantageous in their relation to the requirements of war, and which are difficult of access in roadsteads and ports. On the other hand, it is possible to find for three screws positions which are without inconvenience from the point of view both of fighting and navigation.

"'In short, a circumstance which is most interesting in the case of three propellers is, that of all the positions that have been tested those which are best sheltered by the hull are also those most favorable to speed.

"'In a word, for a vessel of similar form to the *Carpe*, the best plan appears to be to employ a system of three screws placed like those in the second series of experiments, and having a ratio of pitch to diameter differing in little from that ordinarily in use for vessels having single or twin screws.'"

Since these experiments were concluded the French have built the *Dupuy de Lôme*, a triple-screw cruiser of 6,300 tons, whose trials were interrupted by an accident to the boilers. Up to the occurrence of the accident the tests were very satisfactory. The

French are also building the *Massêna*, an ironclad of 11,700 tons, which is to have triple screws.

About the time of the *Carpe* experiments the *Tripoli* was built for the Italian Navy by Armstrong, Mitchell & Co., her keel being laid in 1887. She is a torpedo cruiser of about 800 tons. In 1887 a series of trials was conducted by Mr. F. C. Marshall with one, two and three screws, the results of which are given in the following table:

TABLE SHOWING RESULTS OF TRIALS MADE WITH ONE, TWO AND THREE SCREWS IN THE ROYAL ITALIAN TORPEDO CRUISER *TRIPOLI*.

Number of screws used.	Diameter of screw.	Pitch.	Surface.	Mean revolutions per minute.	I.H.P. (mean.)
	Ft. *in.*	*Ft.* *in.*	*Sq. ft.*		
1	5 3	6 1¼	7·15	356	1,030
2	5 1	6 1¼	6·52	383	2,076
3	5 9	7 1½	7·57	297	3,016

Speed (mean).	Slip.	Draught (mean).	Displacement.
	Per cent.	*Ft.* *in.*	*Tons.*
14·55	32.00	9 10¾	770
18·33	18.6	10 2⅝	802
19.8	5.25	10 5½	831

Length of vessel, 230 feet; breadth, 26 feet.

In speaking of the above trials Mr. F. C. Marshall says:

"They are, perhaps, not strictly comparable, as, owing to local circumstances, they were each made with somewhat different screws; the trials of one and two propellers being made with the same screws, only slightly reduced in diameter for the two-screw trial, while the three-screw trial was made with propellers of larger diameter and greater pitch; and, moreover, as we have not corresponding records of the powers required to drive the vessel the same speed with all three screws, we cannot estimate precisely the propulsive efficiency of one or two screws as compared with the three screws, but it is interesting to note that the

efficiency of the single screw is by no means so small as might have been supposed, considering its small size."

The last sentence of Mr. Marshall hardly gives a fair idea of the efficiency of the single screw. Making allowance for the difference in displacements, and even assuming that the ratio of horse power would vary as the fourth power of the ratio of speeds, the I.H.P. at the lower speed is not greatly in excess of that by calculation.

Had the speed been lower and more appropriate to the size of a single screw, the showing would have been still better.

There are two other triple-screw vessels in the Italian Navy, the *Montebello* and *Monzambano*, sisters of the *Tripoli*, and built shortly afterwards.

The *Kaiserin Augusta* of the German Navy is the only triple-screw vessel of large size whose trials had been completed before those of the *Columbia*. Her displacement on trial was 5,000 tons, and with 12,616 I.H.P. a speed of 20.86 knots was secured. This trial occurred September 29, 1892. Her dimensions are 388 feet, by 51 feet 2 inches, by 21 feet 7 inches; load displacement, 6,500 tons; I.H.P., 13,500; revolutions, 120. The cylinders are 33.47, 65.15 and 86.61 inches diameter by 37.40 inches stroke. There are eight double-end and one single-end boiler, having an aggregate of 1,100 square feet of grate and 33,000 square feet of heating surface. The three screws all have the same diameter, about 14 feet 9 inches, and the pitch of the outer screws is 22 feet 4 inches, while that of the center screw is 21 feet 4 inches. The projection of the screws on an athwartship plane shows their axes to lie in the same horizontal plane, the disc circle of the center one slightly overlapping those of the outer ones. The axes of the outer screws are about 26 feet apart. The center screw is 18 feet abaft the side screws.

Before the vessel was tried it had been anticipated that the center screw would revolve more rapidly than the side screws, but this did not prove to be the case, the central screw making about five or six revolutions per minute fewer than the side screws.

The *Columbia*, then known officially as *Cruiser No. 12*, and

popularly as the *Pirate*, was designed in 1890. Triple screws were adopted on the recommendation of Engineer-in-Chief Melville. The reasons leading to their adoption were given on p. 410 of vol. II of this JOURNAL, as follows:

"The special advantages of triple screws are smaller size of separate parts of the machinery, enabling higher rotative speeds to be employed with safety, and greater economy in ordinary cruising, when one engine working up to about its natural draft full power will give a fair cruising speed with economy of fuel. It is far from economical to run large twin-screw engines, designed for 19 knots and upwards, at speeds of 9 and 10 knots. Engine friction alone forms such a large percentage of the power developed, to say nothing of the increased cylinder condensation due to slower rotative speeds, that the economic performance, as measured by coal per I.H.P., is very low. The slip of the single screw will, of course, be enormously greater; but it was shown years ago by Chief Engineer Isherwood's Mare Island screw experiments that a very large increase of slip may be attended with a very small reduction in total propelling efficiency."

To these may be added that, as the designed horse power was in excess of that developed by any of our other vessels, and as no shafts had at that time been constructed in this country to transmit one-half that power, it was an additional advantage that triple screws would keep the stress on each shaft down to little over 7,000 I.H.P. It is also an incidental advantage that the chances of total disablement are reduced.

Having thus glanced at the history of multiple screws, we may now proceed with the detailed description of the *Columbia*.

The *Columbia* was designed by the Navy Department and built by the Wm. Cramp & Sons Ship and Engine Building Company of Philadelphia. The contract price for hull and machinery was $2,725,000, and it was stipulated that a speed of 21 knots should be maintained for four consecutive hours in the open sea, with an air pressure of one inch of water in the fire rooms. By the contract, the builders were to be paid a premium of $50,000 for each quarter knot the ship made over 21 knots, and for each quarter knot the speed fell short of 21 knots a penalty of $50,000

was to be exacted by the Government. The contract also provided that all material used in the construction of the hull and machinery should be of domestic manufacture.

As the vessel is a commerce destroyer, she closely resembles in appearance a merchant steamer. She has two pole masts without military tops, and four smoke pipes. She has a large coal capacity, and it is estimated that she can steam upwards of 12,000 knots at 10 knots per hour.

The hull is built of open-hearth mild steel and is shaped to give high speed, the lines being very fine. A much larger space than is usual in a war vessel is given up to the machinery, but, owing, however, to the reduced armament, ample space remains for quartering the officers and crew.

The accompanying illustrations give an excellent idea of the general appearance of the ship and of the internal arrangement, and of one of the propelling engines.

The photograph of the ship shows her as she was crossing the line and entering on the great race against time. It is from a copyrighted photograph by Mr. Wm. H. Rau, of Philadelphia, who has given permission for its reproduction here.

The picture of one of the main engines was taken just prior to dismantling it in the shop. On the left will be noticed a part of one of the other engines.

The *Columbia* is the longest vessel in the Navy. The original design called for a ship 400 feet in length, but it was modified, and three additional frames, *A*, *B* and *C*, were inserted between frames 53 and 54, as shown on the accompanying plates. The midship section, which is at frame B, cuts the after end of the third pair of main boilers. Bilge keels extend from frame 35 to frame 71. Each pair of main boilers and each main engine is in a separate water-tight compartment, fitted with water-tight doors, which in the fire rooms open into air locks. The boiler and engine compartments extend from frame 32 to frame 82. Under the protective deck forward of the boiler compartments is an athwartship coal bunker, over which is the dynamo room. Forward of these are store rooms, and forward of the store rooms is one of the magazines and one of the shell rooms, above which is

the ammunition-passing room; forward of these are the chain lockers and hold, and then the bread room, and lastly, in the bow, is the trimming tank. Under the protective deck, abaft the center engine room, is the shaft alley and engineers' store rooms, above which are other magazines and shell rooms with a passing room over them, and also the steering room, in which are the steering engine and gear, and rooms for hospital and ward room mess stores. Tanks and store rooms are fitted in the engine rooms against the sides of the ship, and coal bunkers abreast the fire rooms below the protective deck. On the protective deck forward are rooms for sails and awnings, ship's stores and warrant officers' mess stores. On this deck over the fire rooms are the boiler uptakes, ventilators, evaporator room, two auxiliary fire rooms, coal bunkers and rooms for ship-ventilating fans. Over the engine rooms are coal bunkers and the engine hatches, and against the ship's sides from frame 6 to frame 98 extend the cofferdams, and a passageway to give communication from aft forward past the engines and boilers. Abaft the engine rooms on this deck is the workshop, within which are the two quarter torpedo tubes, and abaft these are rooms for paymasters' and officers' mess stores, while at the stern is the stern torpedo tube and the spare tiller room, within which is the spare tiller for use with tackles in case of failure of the regular steering gear. On the berth deck, which may be considered a part of the protective deck, forward is situated the store room for dry provisions, the two bow torpedo tubes, part of the living space for the crew, and and at the bow the sick bay.

The gun deck may be called the living deck, as it contains all of the quarters for the officers and men except the state rooms and offices of the executive officer and navigator and the small portion of the above-mentioned crew's space. Part of the ship's battery is on this deck. The captain's quarters, consisting of a cabin, two state rooms, pantry and office, are at the stern and are finished in mahogany. Forward of these are the quarters of the ward-room officers, consisting of a dining room (running across the ship and extending from frame 76 to frame 80) and forward and aft of the dining room two countries, into the after one of

which open six state rooms and into the other ten, making altogether, with the two rooms on the deck above, accommodations for eighteen ward-room officers. Off the forward country, which extends as far forward as the forward engine rooms, are the bath rooms, with tubs and shower rooms, and the pantry for the ward room, and in it are the two large engine hatches.

The auxiliary boiler rooms, smoke pipes, hatches, ventilators and firemen's wash rooms extend along the center of this deck over the main fire rooms; and along the sides of the deck, from frame 63 to frame 45, extend on the starboard side the three state rooms of the junior officers, their dining room, store room, pantry and lavatory, and the machinists' lavatory; on the port side the two state rooms and pantry of the warrant officers, the paymaster's office, the engineer's log room, the officers' closets and the machinists' rooms. On the forward part of this deck are the lamp room, crew's closets and wash room, the prison and the steam windlass. The remainder of this deck is devoted to living space for the crew. The ends of the upper deck are clear for use of the larger guns.

Within the superstructure are the rooms and offices for two officers, the armory, the hatches, ventilators, galleys, ice machine, cold storage room, etc. Forward on the bridge deck is the pilot house, under which is the conning tower and armored tube. The winches, boats, and part of the steering wheels are also on this deck; while down the center extend the smoke pipes, ventilators and hatches.

The ship is well ventilated and well lighted both by day and at night. The living quarters are large and airy, and fitted with many improvements and conveniences. The quarters of all officers except the captain are finished in ash.

ARMAMENT.

The *Columbia* is armed with two 6-inch 40-caliber rifles mounted forward; one 8-inch 40-caliber rifle mounted aft for stern fire; eight 4-inch R. F. guns in 4-inch sponsons on the gun deck; eight 6-pounder R. F. guns in 2-inch sponsons on the gun deck; four 6-pounder R. F. guns on the upper deck. In addi-

tion, there are four 0.45-caliber Gatling guns and four 1-pounder R. F. guns. There are five torpedo tubes, one on each bow, one on each quarter, and one discharging astern.

There is a 5-inch conning tower, with a 3-inch tube for communication. The protective deck extends the entire length of the ship and is made up of two courses of 1¼-inch nickel steel, and on the slopes over the engine rooms it is increased by an additional course 1½-inch thick, making the thickness of those parts 4 inches and for the remainder of the deck 2½ inches.

HULL.

Length between perpendiculars, feet and inches	411–7¼
Length on L.W.L., feet and inches	411–7¼
Length over all (including rudder), feet and inches	414–10
Beam, extreme, feet and inches	58–2¼
Beam at L.W.L, feet and inches	58–2¼
Ratio of length to beam	7.08
Depth of hold from top of main-deck beams to top of floors, feet and inches	37–3
Draught forward, sea-going trim, feet and inches	24–0
Draught aft, sea-going trim, feet and inches	24–0
Draught mean, sea-going trim, feet and inches	24–0
Depth of keel below skin, feet and inches	0–0
Displacement, sea-going trim (load draught), tons	8,050
Displacement per inch at L.W.L., tons	37.4
Area of immersed midship section, sea-going trim, square feet	1,212
Area of L.W.L. plane, square feet	15,600
Center of gravity of L.W.L. plane aft of midship section (frame No. B), feet and inches	4–8⅜
Center of buoyancy above bottom of keel, feet and inches	14–1½
Center of buoyancy aft of midship section, feet and inches	2–3½
Center of gravity above bottom of keel, feet and inches	21–9½
Transverse metacenter above center of buoyancy, feet and inches	10–7
Longitudinal metacenter above center of buoyancy, feet	458
Distance from center of gravity to transverse metacenter, feet and inches	2–10¾
Distance from center of gravity to longitudinal metacenter, feet and inches	430–3½
Coefficient of displacement	0.4909
Coefficient of midship section	0.869
Coefficient of L.W.L	0.652
Cylindrical coefficient	0.566
Wetted surface (estimated), square feet	28,904
Number of frames	109
Number of water-tight compartments	205

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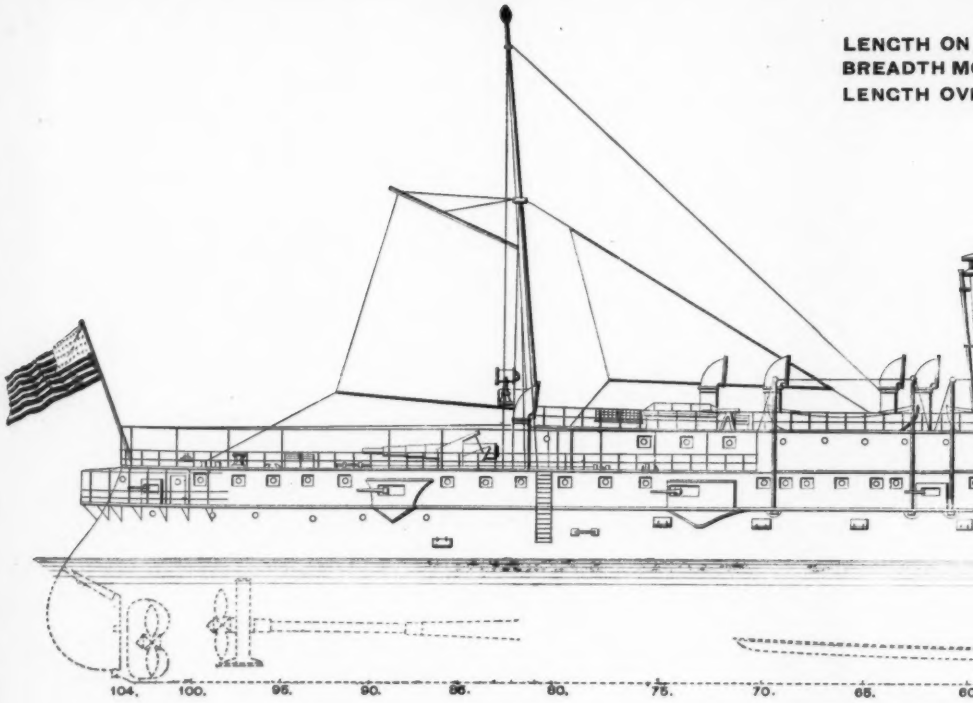
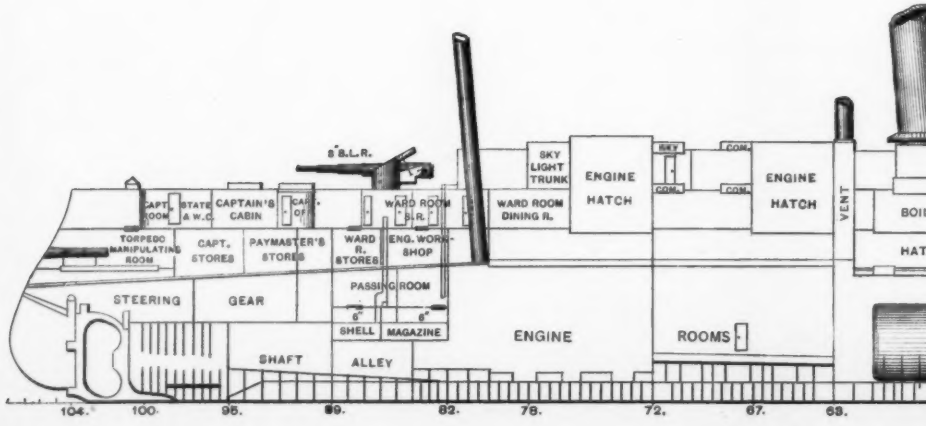
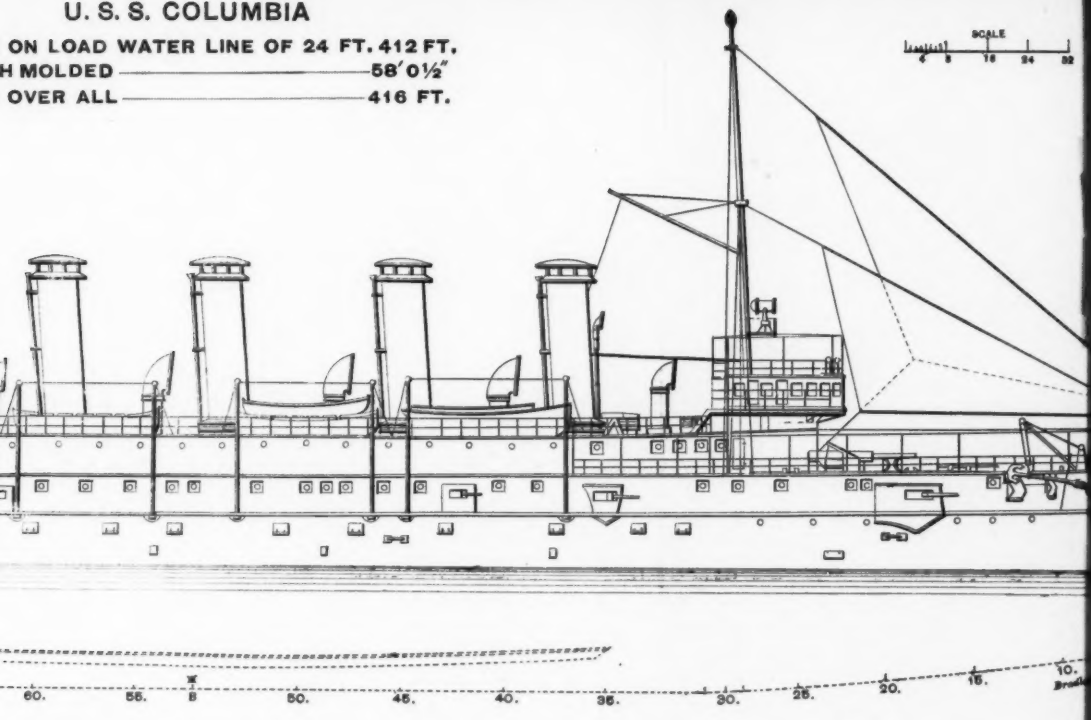
BREADTH M
LENGTH OV

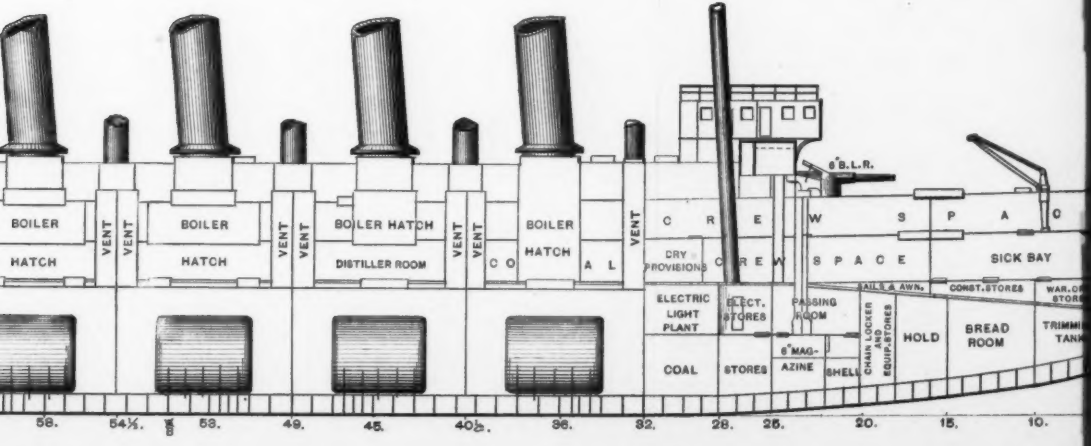


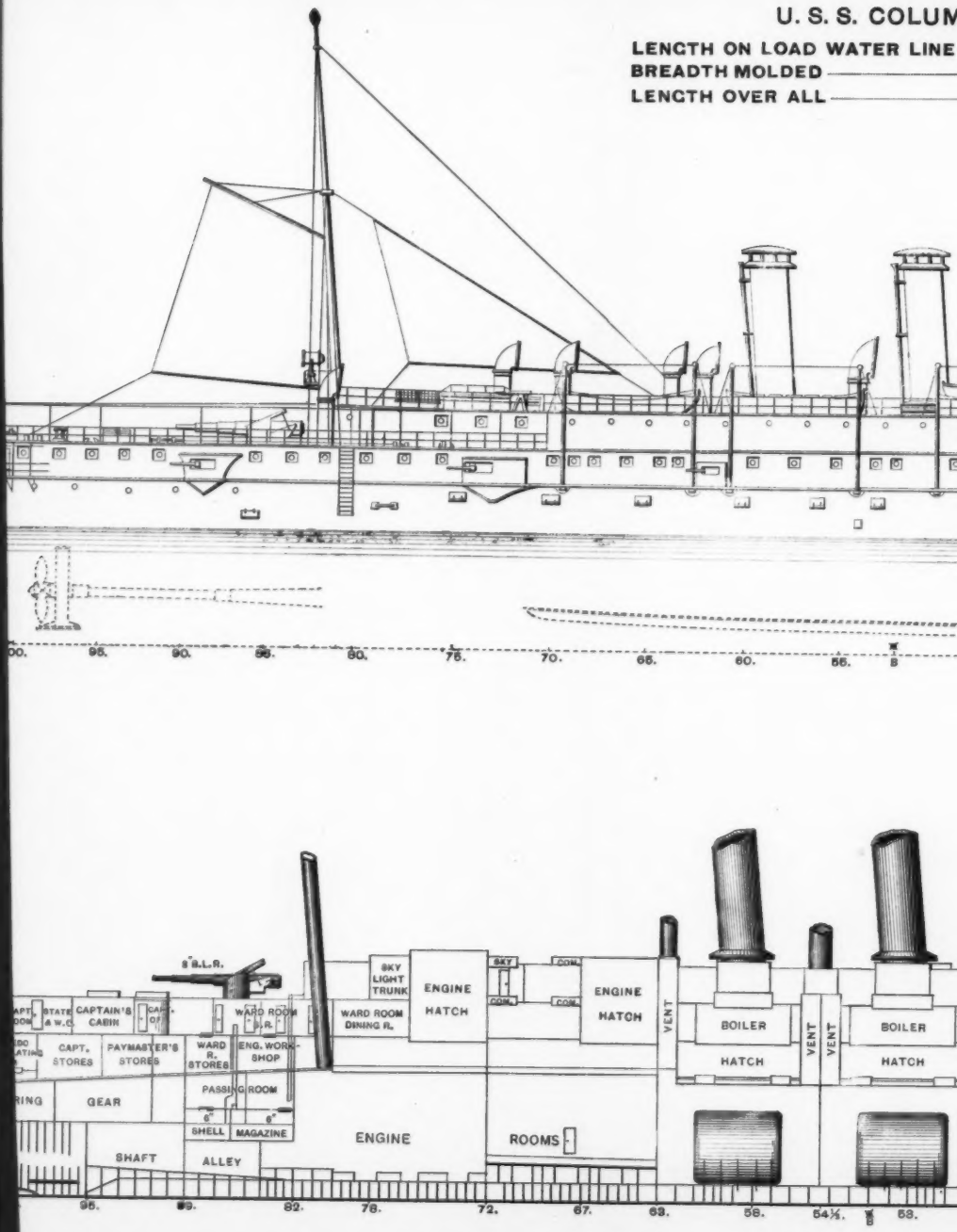


U. S. S. COLUMBIA

ON LOAD WATER LINE OF 24 FT. 412 FT.
H MOLDED ——— 58′ 0½″
OVER ALL ——— 416 FT.






U. S. S. COLUM
LENGTH ON LOAD WATER LINE
BREADTH MOLDED
LENGTH OVER ALL
100.
95.
90.
85.
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60.
55.
B
8" B.L.R.
CAPT. ROOM
STATE & W.C.
CAPTAIN'S CABIN
CAPT. OFF.
WARD ROOM
W.R.
SKY LIGHT TRUNK
ENGINE HATCH
WARD ROOM DINING R.
SKY
COM.
ENGINE HATCH
VENT
BOILER HATCH
VENT
VENT
BOILER HATCH
CAPT. STORES
PAYMASTER'S STORES
WARD R. STORES
ENG. WORK-SHOP
RING
GEAR
PASSING ROOM
6"
6"
SHELL
MAGAZINE
ENGINE
ROOMS
SHAFT
ALLEY
96.
89.
82.
76.
72.
67.
63.
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54½.
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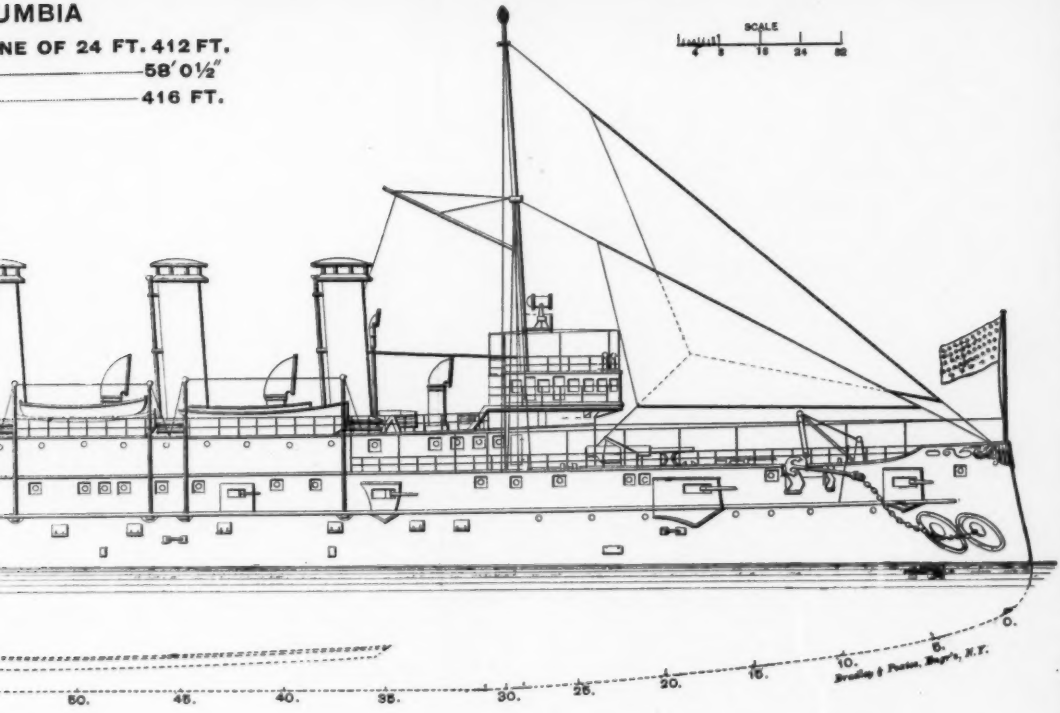
53.

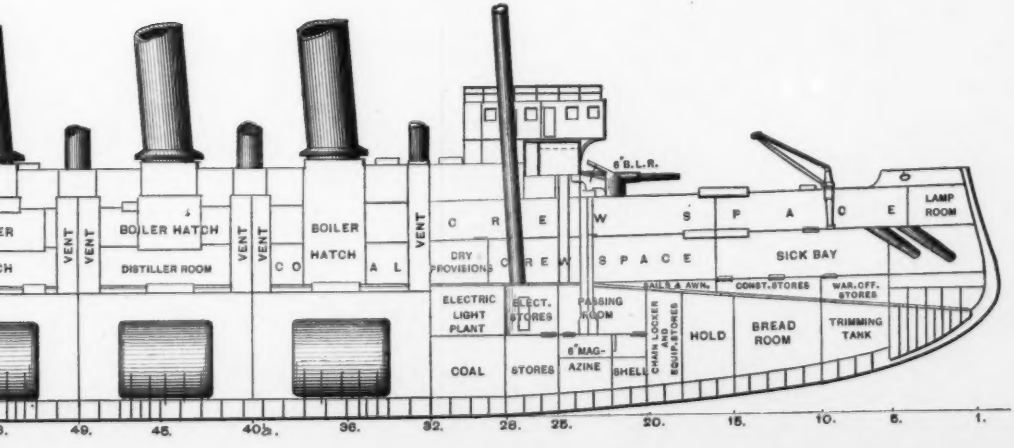
UMBIA

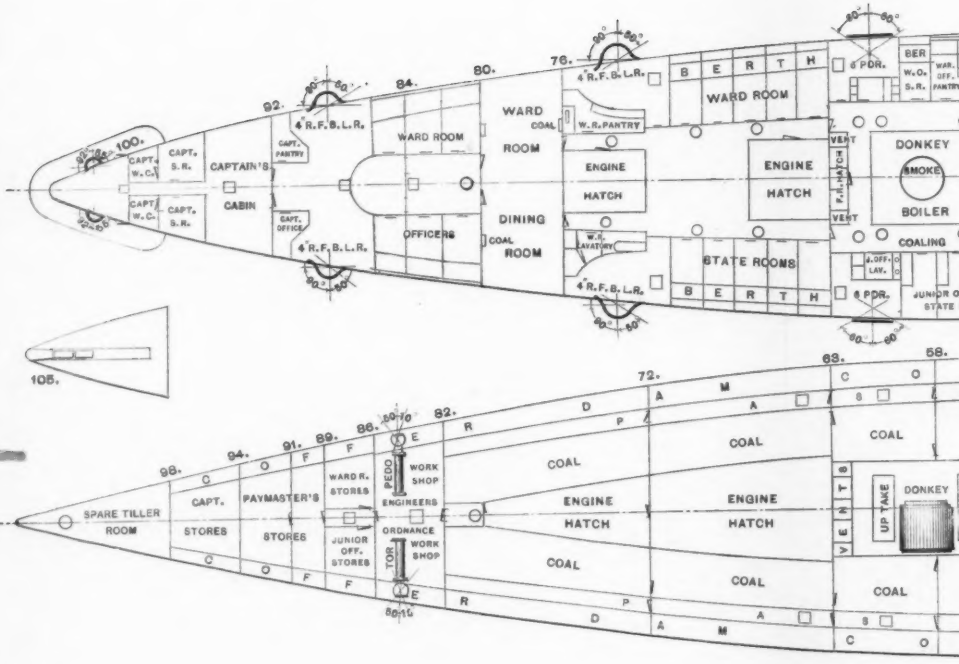
NE OF 24 FT. 412 FT.

58′ 0½″

416 FT.






105.
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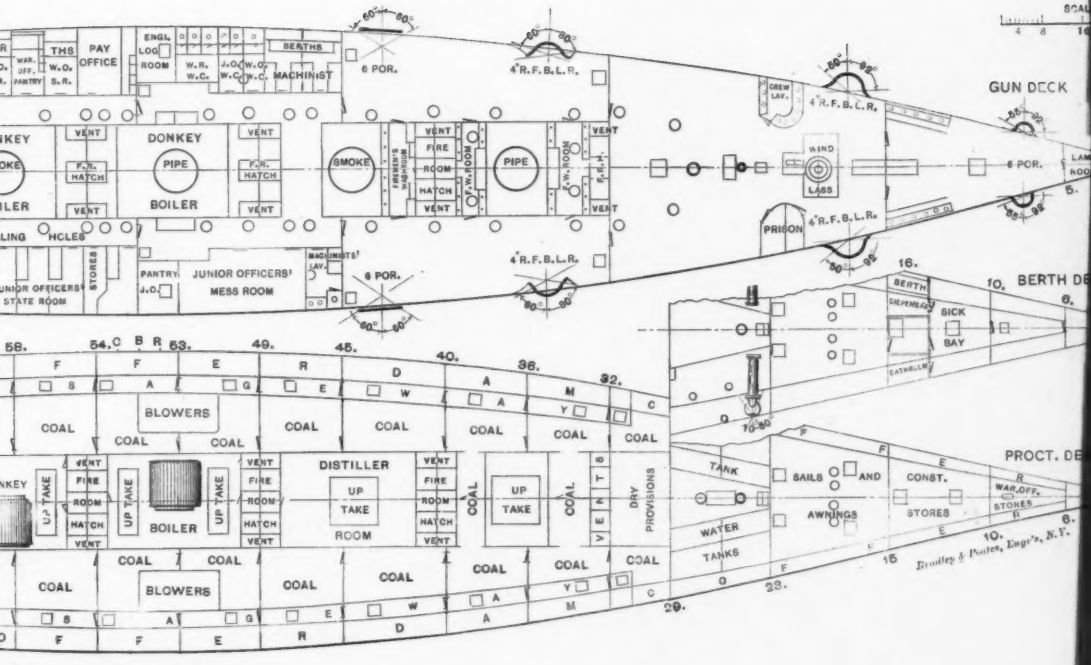
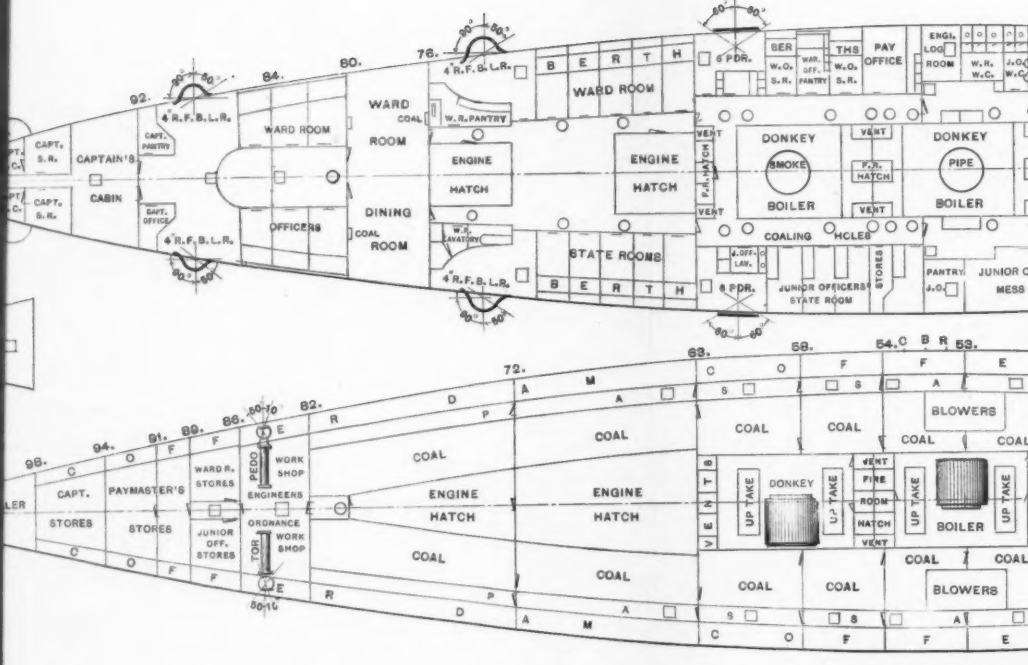
4 R.F.B.L.R.
6 PDR.
CAPT. W.C.
CAPT. S.R.
CAPTAIN'S CABIN
CAPT. PANTRY
CAPT. OFFICE
WARD ROOM
OFFICERS
WARD ROOM COAL
WARD ROOM
DINING ROOM
COAL
W.R. PANTRY
W.R. LAVATORY
ENGINE HATCH
ENGINE HATCH
WARD ROOM
STATE ROOMS
BERTH
VENT
F.H. HATCH
DONKEY
SMOKE
BOILER
COALING
4 OFF. LAV.
JUNIOR OFFICERS STATE
WAR. OFF. PANTRY
W.C.
S.R.
SPARE TILLER ROOM
CAPT. STORES
PAYMASTER'S STORES
WARD R. STORES
JUNIOR OFF. STORES
TORPEDO
WORK SHOP
ENGINEERS
ORDNANCE WORK SHOP
COAL
ENGINE HATCH
ENGINE HATCH
UP TAKE
DONKEY
VENTILATORS
COFFERDAM
FORE PEAK
AFT PEAK



U. S. S. COLUMBIA


CAPTAIN'S CABIN
CAPT. S. R.
CAPT. PANTRY
CAPT. OFFICE
4 R.F.B. L.R.
WARD ROOM
OFFICERS
WARD ROOM
DINING ROOM
COAL
W.R. PANTRY
W.R. LAVATORY
ENGINE HATCH
ENGINE HATCH
STATE ROOMS
BERTH
6 PDR.
BER
W.O. S.R.
WARD. OFF. PANTRY
THS
W.O. S.R.
PAY OFFICE
ENGI. LOG ROOM
W.R.
W.C.
DONKEY
SMOKE
BOILER
F.W. HATCH
DONKEY
PIPE
BOILER
VENT
COALING HOLES
4 OFF. LAV.
JUNIOR OFFICERS STATE ROOM
STORES
PANTRY
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MESS
COAL
ENGINE HATCH
ENGINE HATCH
COAL
COAL
COAL
BLOWERS
UP TAKE
DONKEY
VENT
FIRE ROOM
HATCH
BOILER
CAPT. STORES
PAYMASTER'S STORES
WARD R. STORES
JUNIOR OFF. STORES
PEDO
WORK SHOP
ENGINEERS
ORDNANCE
TOR
WORK SHOP
98.
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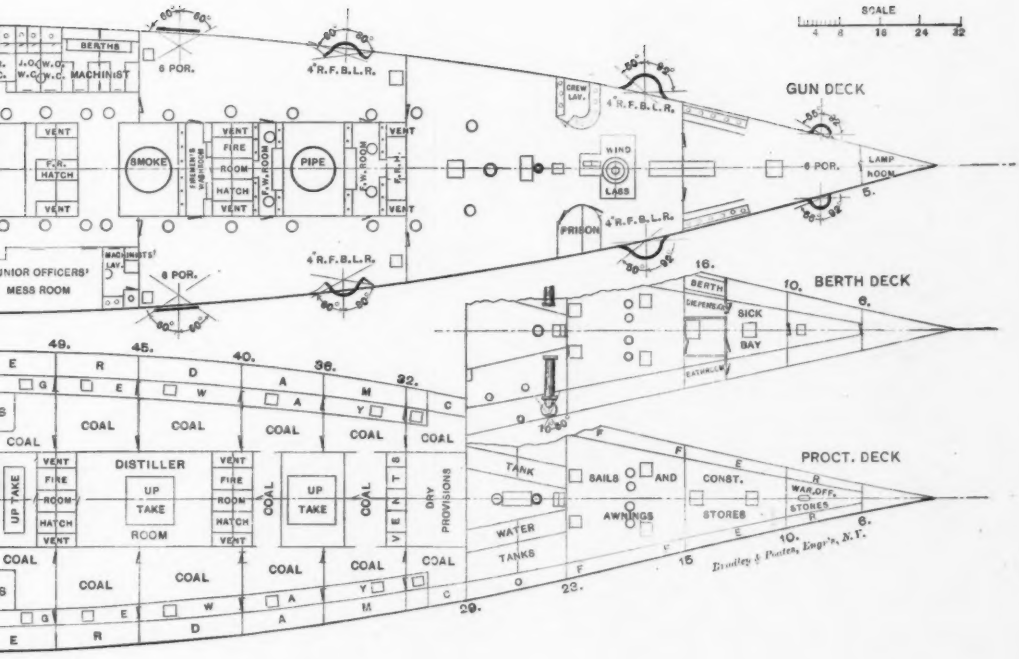
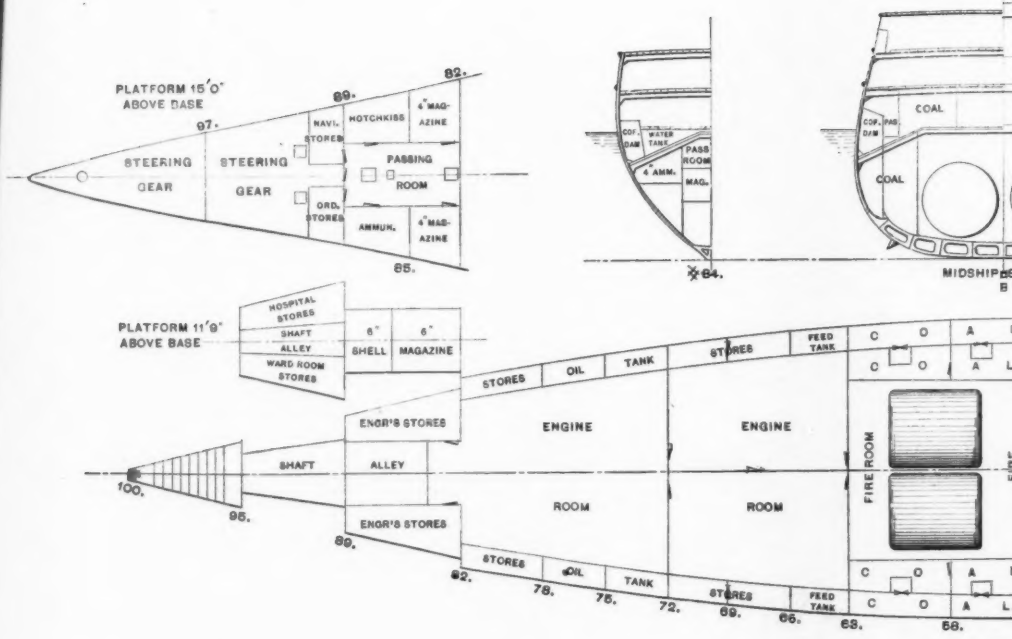
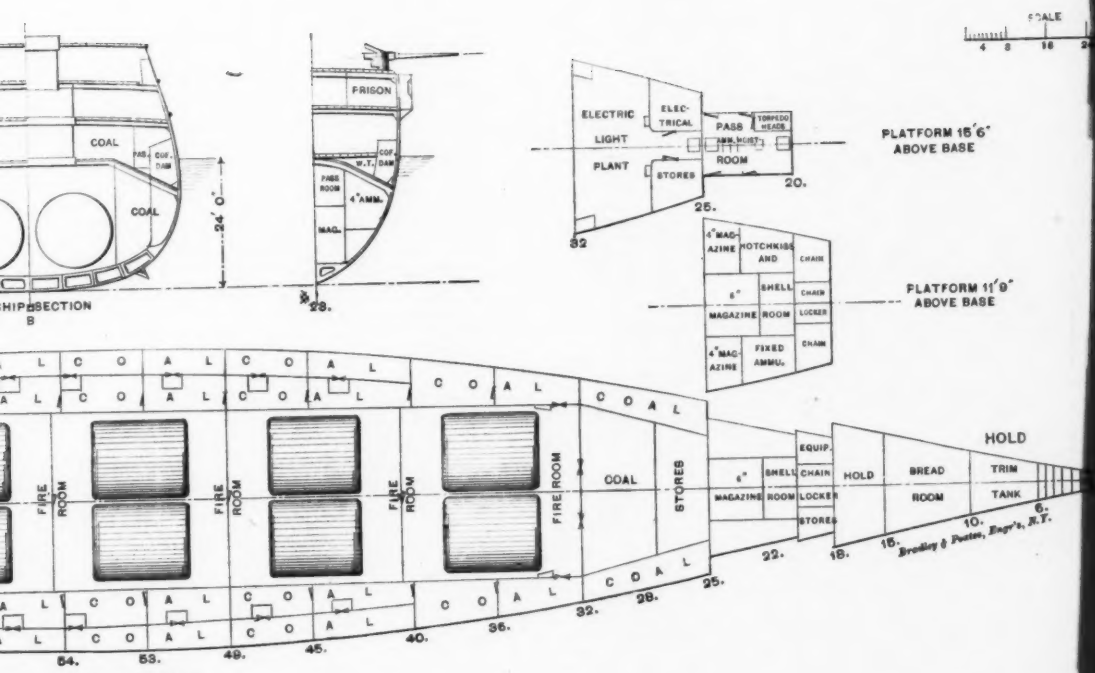
U.S.S. COLUMBI


SCALE
4 8 16 24 32
GUN DECK
BERTH DECK
PROCT. DECK
BERTHS
6 POR.
4" R.F.B.L.R.
SMOKE
PIPE
VENT
F.R. HATCH
FIRE ROOM
E.N. ROOM
WIND LASS
CREW LAV.
PRISON
LAMP ROOM
SICK BAY
BATHROOM
JUNIOR OFFICERS' MESS ROOM
MACHINISTS' LAV.
COAL
DISTILLER ROOM
UP TAKE
DRY PROVISIONS
TANK
WATER TANKS
SAILS AND AWNINGS
CONST. STORES
WARDOFF STORES
Bradley & Porter, Engr's, N.Y.

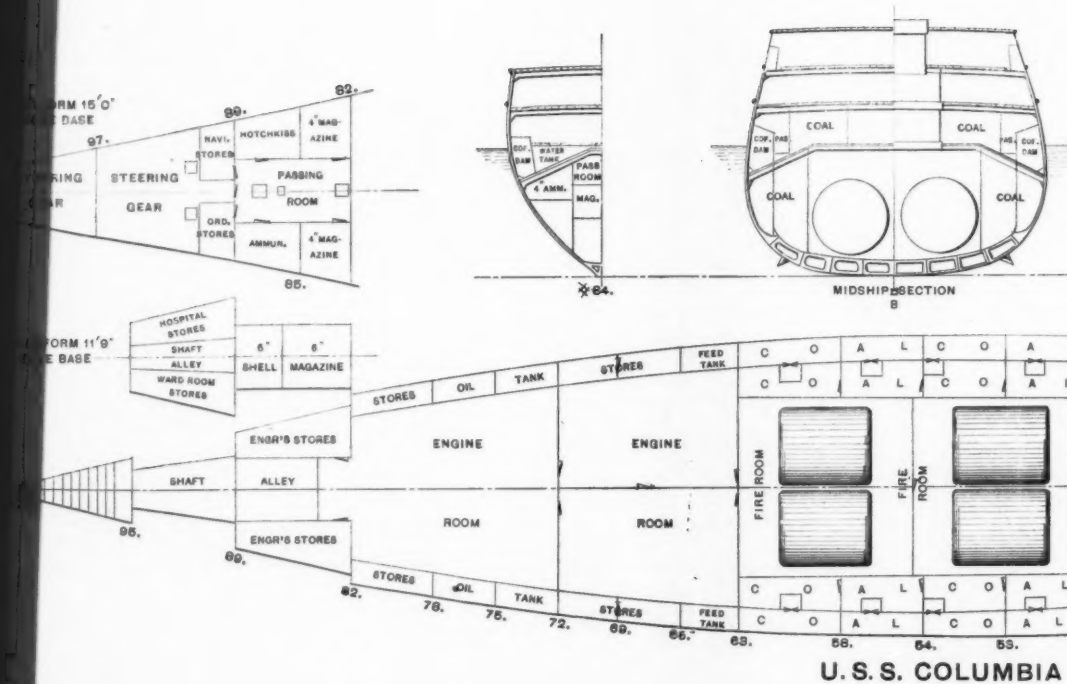
IBIA


PLATFORM 15'0" ABOVE BASE
97.
89.
82.
NAVI. STORES
HOTCHKISS
4" MAG-AZINE
STEERING GEAR
STEERING GEAR
PASSING ROOM
ORD. STORES
AMMUN.
4" MAG-AZINE
85.
COF. DAM
WATER TANK
PASS ROOM
4" AMM.
MAG.
COAL
COF. DAM
PAS.
COAL
X64.
MIDSHIP
PLATFORM 11'9" ABOVE BASE
HOSPITAL STORES
SHAFT ALLEY
WARD ROOM STORES
6"
6"
SHELL
MAGAZINE
STORES
OIL
TANK
STORES
FEED TANK
ENGR'S STORES
ENGINE
ENGINE
SHAFT
ALLEY
ROOM
ROOM
FIRE ROOM
ENGR'S STORES
100.
95.
89.
82.
78.
75.
72.
69.
66.
63.
58.
STORES
OIL
TANK
STORES
FEED TANK

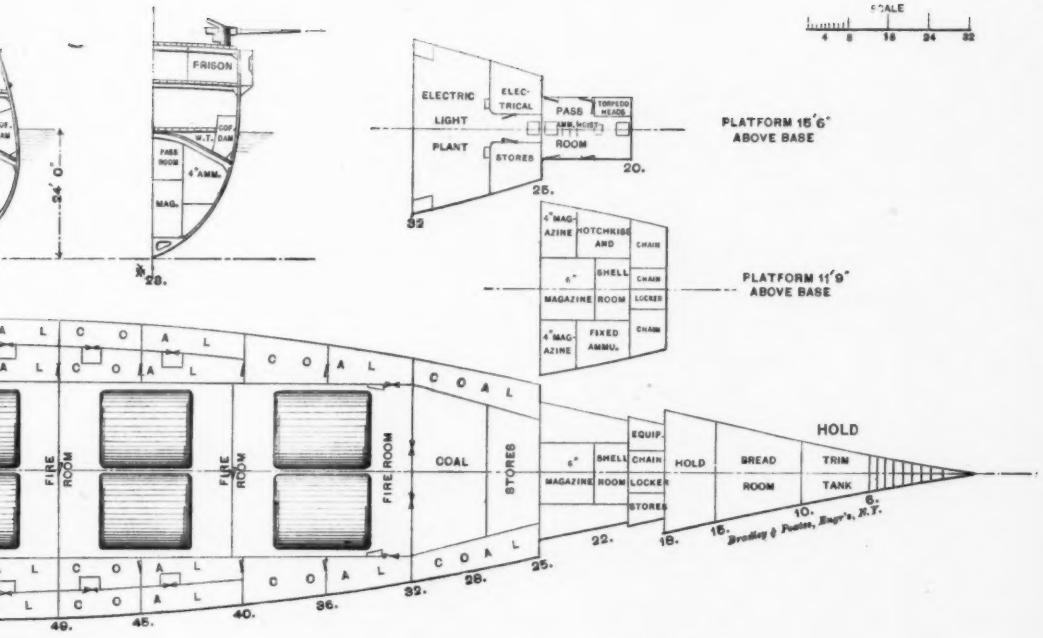
U. S. S.


SCALE
4 8 16 24
COAL
COAL
24' 0"
FRISON
4" AMM.
MAG.
28.
SECTION
B
ELECTRIC LIGHT PLANT
ELEC-TRICAL
STORES
PASS
TORPEDO HEADS
TORP. HOIST
ROOM
20.
25.
32
PLATFORM 15'6" ABOVE BASE
4" MAG-AZINE
HOTCHKISS AND
CHAIN
6"
SHELL
MAGAZINE
ROOM
LOCKER
4" MAG-AZINE
FIXED AMMU.
PLATFORM 11'9" ABOVE BASE
COAL
FIRE ROOM
STORES
EQUIP.
HOLD
BREAD
ROOM
TRIM
TANK
54.
53.
49.
45.
40.
36.
32.
28.
25.
22.
18.
15.
10.
6.
Bradley & Porter, Eng'rs, N.Y.

S. S. COLUMBIA



U. S. S. COLUMBIA


SCALE
4 8 16 24 32
PRISON
24' 0"
28.
ELECTRIC LIGHT PLANT
ELEC-TRICAL
STORES
PASS
TORPEDO HEADS
AMM. HOIST
ROOM
PLATFORM 15'6" ABOVE BASE
20.
25.
32
4" MAG-AZINE
HOTCHKISS AND
CHAIN
6" MAGAZINE
SHELL ROOM
CHAIN
LOCKER
4" MAG-AZINE
FIXED AMMU.
CHAIN
PLATFORM 11'9" ABOVE BASE
COAL
FIRE ROOM
COAL
STORES
EQUIP.
CHAIN
LOCKER
STORES
HOLD
BREAD ROOM
TRIM TANK
22.
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Bradley & Foster, Engr's, N.Y.

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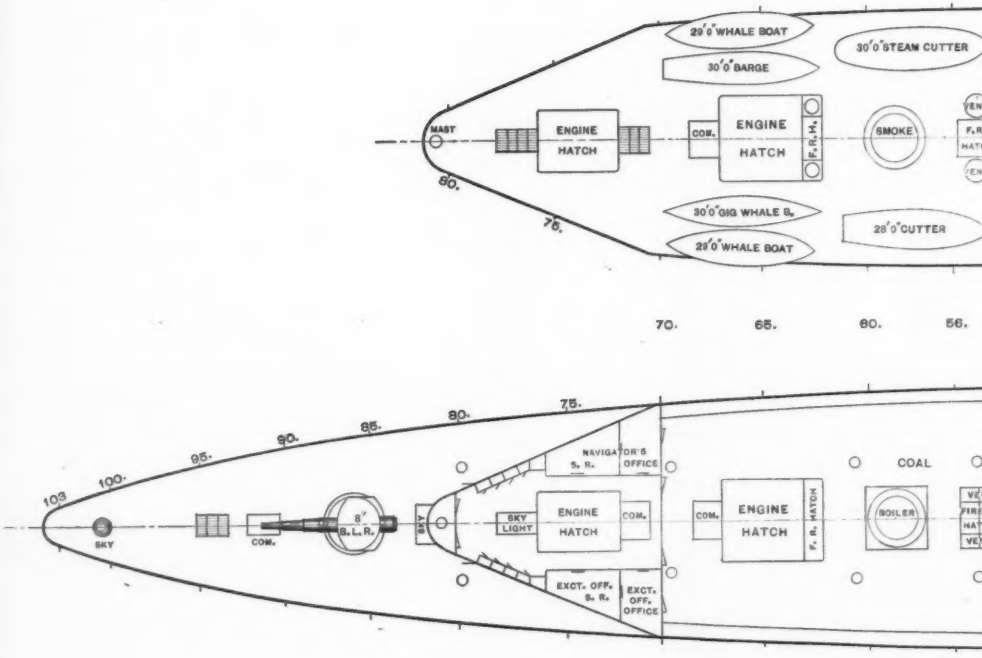
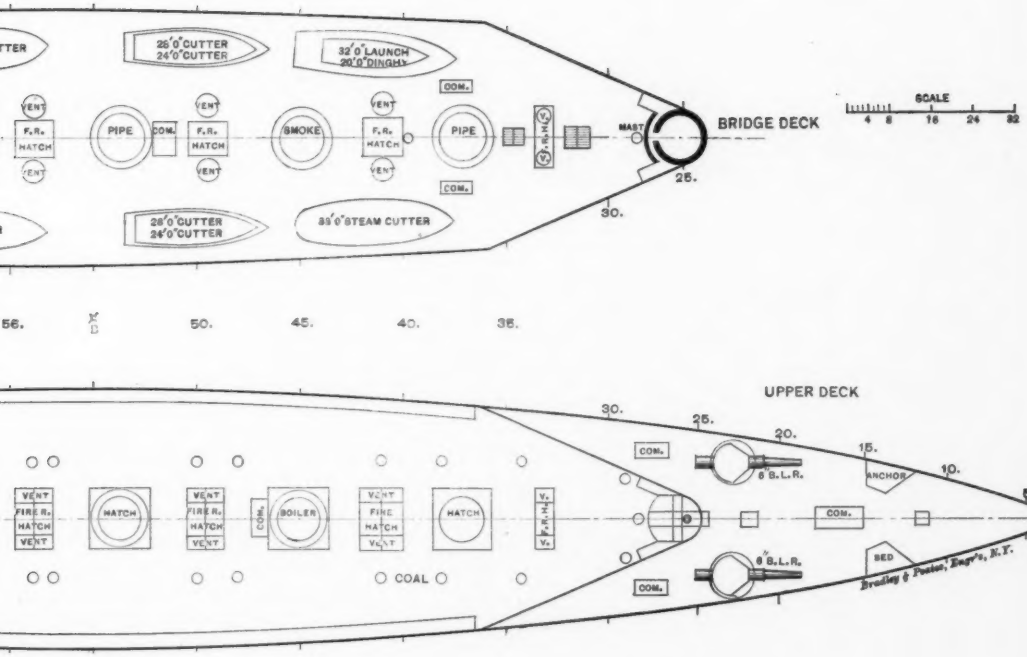

29'0" WHALE BOAT
30'0" STEAM CUTTER
30'0" BARGE
MAST
ENGINE HATCH
COM.
ENGINE HATCH
F.R.H.
SMOKE
60.
75.
30'0" GIG WHALE B.
28'0" CUTTER
23'0" WHALE BOAT
70.
65.
80.
56.
75.
85.
90.
95.
100.
103
NAVIGATOR'S OFFICE
S. R.
COAL
SKY
COM.
8" B. L. R.
SKY
SKY LIGHT
ENGINE HATCH
COM.
COM.
ENGINE HATCH
F. R. HATCH
BOILER
EXCT. OFF. S. R.
EXCT. OFF. OFFICE

U.



U. S. S. COLUMBIA

Keel, depth, feet and inches 3–6
weight, pounds 20
top angles ..... $3\frac{1}{2} \times 3 \times 10$ lbs.
bottom angles ..... $4 \times 3 \times 12$ lbs.
Non-water-tight lightening holes entire length of keel.
Inner bottom, extends from frame 24 forward to frame 89 aft, a distance of 280 feet.
Water-tight compartments extend across the ship between third longitudinals.
Cofferdam, extends the entire length of vessel on protective deck.
height, feet and inches 7–6
width, feet and inches 5–0
weight of cellulose to fill, pounds 199,000

MAIN ENGINES.

There are three vertical, inverted, direct-acting, three-cylinder, triple-expansion engines, placed each in a separate water-tight compartment. The engines working the port and starboard propellers are abreast each other and forward of the center engine. The H.P. cylinders of the former are aft, and the H.P. cylinder of the center engine is forward. The I.P. and L.P. cylinders are steam-jacketed on the sides and bottom. There are for each engine two receivers, consisting of exhaust pipes and valve chests, the safety valves of which are set at 95 and 25 pounds. The cylinders are supported by three cast-steel inverted Y-frames on one side and by six wrought-steel columns on the other, the whole being securely fastened by tie rods. Each engine has one high-pressure two intermediate-pressure, and four low-pressure, single-ported piston valves. There are four double-bar Stephenson links. The cut-off for each link is independent of the others and momentarily adjustable by means of hand screw gear fitted to slots in the arms of the reversing shaft which runs the link in or out. The shafts and working parts generally are forged of mild open-hearth steel. The engine bed plates are each formed of three steel castings bolted together.

The reversing gear may be worked either by steam or hand. It consists of a vertical steam cylinder hinged to the engine bed plate, of an oil (non-controlling) cylinder placed above the steam cylinder, and of a hand pump secured to the bed plate on the opposite side of the engine. The diameters of the steam and oil cylinders are 16 and 8 inches, respectively, and the common

stroke is 22 inches, the two pistons being on one rod. In case of accident to the steam gear, the hand pump may be used to force oil into either end of the oil cylinder. Motion is transmitted from the piston rod to an arm of the reversing shaft.

There is a pair of simple vertical turning engines, with cylinders 8 inches diameter by 6 inches stroke, secured to the bed plate of the main engine between the I. P. and L. P. engine frames. On the shaft of the turning engine there is a worm, and opposite it on the couplings of the propelling shaft a worm wheel; there is also a short pivoted shaft, having a worm wheel on one end and a worm on the other, which may at will be made to engage the worm and worm wheel on the two crank shafts. These engines can readily, though slowly, turn the propelling engines with steam of 60 pounds pressure, and may be readily connected and disconnected.

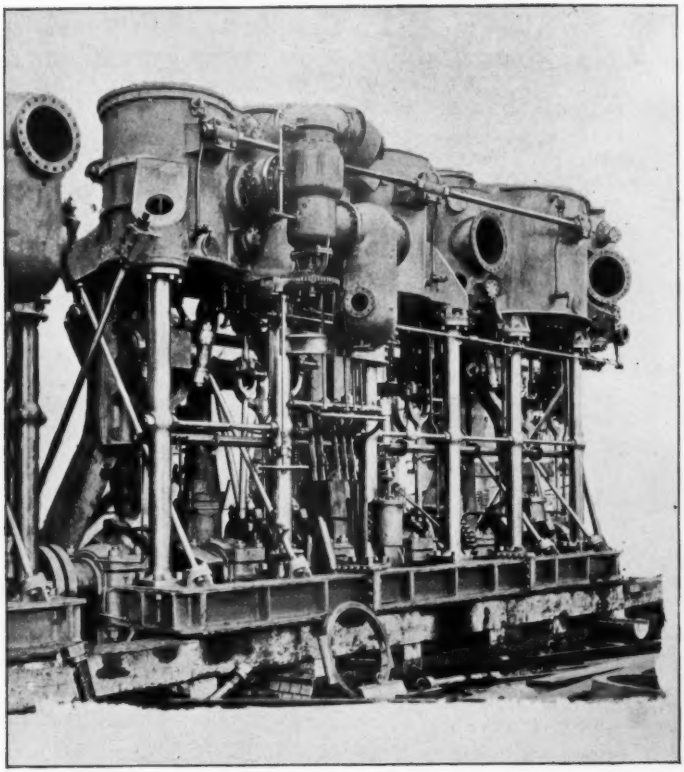
The eccentric straps are made of composition, and, like the crank-shaft brasses and caps, are lined with Parson's white brass.

Attached to the main steam pipe at each engine is a steam separator, having a division plate extending part way to the bottom; and between the separator and the H. P. valve chest are a disc stop valve, having a balance piston, and a butterfly throttle.

The main steam pipes are lap-welded steel tubes, with hydraulic-machine turned flanges. There are valves in the two main steam pipes which may be operated from above the protective deck.

High up in the center engine room is placed a 40-gallon oil tank, from which distributing pipes lead to the various engines. A small Blake duplex pump draws from the main oil tanks and delivers through a strainer into the distributing tank.

Number of cylinders of each main engine	3
Diameter of H.P. cylinders, inches	42
Diameter of I.P. cylinders, inches	59
Diameter of L.P. cylinders, inches	92
Stroke of all pistons	42
Diameter of H.P. valve (one for each cylinder), inches	18
Diameter of I.P. valves (two for each cylinder), inches	23
Diameter of L.P. valves (four for each cylinder), inches	21



ENGINES OF THE U.S.S. "COLUMBIA."

Area of steam ports for maximum opening...	H.P. cylinder, square inches..	201.46
	I.P. cylinder, square inches...	301.
	L.P. cylinder, square inches...	519.
Area of exhaust ports for maximum opening.	H.P cylinder, square inches..	207.21
	I.P. cylinder, square inches...	385.
	L.P. cylinder, square inches...	767.
Area of main steam pipe to engine (20 inches diameter), square inches		314.16
Area of each of two main exhaust pipes (22½ inches diameter), square inches..		397.61
Volume swept by H.P. piston per stroke, mean, cubic feet		33.04
Volume swept by I.P. piston per stroke, mean, cubic feet		65.82
Volume swept by L.P. piston per stroke, mean, cubic feet		160.94
Ratio of net area of H.P. to I.P. pistons		1.99
Ratio of net area of I.P. to L.P. pistons		2.44
Ratio of net area of H.P. to L.P. pistons		4.87
Diameter of piston rods, inches		8½
Length of piston rods from piston to crosshead, inches		63½
Length of connecting rods, from center to center, inches		71
Diameter of upper end of connecting rods, inches		8
Diameter of lower ends of connecting rods, inches		10½
Thickness, sides and faces, of connecting rods, inches		8
Diameter of crosshead bolts (4), inches		3¾
Diameter of crank-pin bolts (2), inches		4⅛
Crosshead surface, ahead gear, 24×26 inches, square inches		624
Diameter of crosshead pins, inches		9
Length of crosshead pins, inches		11

Shafting and Bearings.—All of the shafting is hollow and made of steel. Each crank shaft is made in three interchangeable and reversible sections, and to accomplish this the H. P. eccentrics are fitted on other shafts. For the starboard and port engines, with the H. P. cylinder forward, a single-collar shaft, 16½ inches long, is used, and for the center engine, with the H. P. cylinder aft, the eccentrics are carried by the forward line shaft, which is 3 feet in length. The shafting for both the port and starboard engines is made up of the short extension shaft, the three sections of crank shaft, one line shaft, one thrust shaft, one stern shaft, and one propeller shaft. For the center engine the shafting comprises the three sections of crank shaft, one short line shaft, one thrust shaft, one long line shaft, and one propeller shaft. Provision is made for allowing the idle propellers (or propeller) to revolve, when only one (or two) of the engines are being used, by disconnecting the couplings next forward of the

thrust bearings. The bolts in these couplings are tapered and those in all of the other couplings are straight. A friction brake or clamp is fitted to each line of shafting abaft the disconnecting coupling for the purpose of keeping the shafting from revolving when the ship is under weigh and it is desired to couple the shafting. The forward end of the stern shaft of each side engine, and of the propeller shaft of the center engine, is tapered and fitted twenty inches into a socket formed on the after end of the next forward section of the shafting, and a longitudinal key fitted along the tapered surfaces. The straight part of the shaft adjacent to the taper is threaded and the nut thereon is secured to the end of the socket by tap bolts. The object of these socket couplings is, of course, to permit the withdrawal outward of the shafts from the stern tubes. The rudder post has a hole formed in it, and the forward edge of the rudder is recessed, so that when the rudder is put hard over the center propeller shaft may be removed. The hole in the rudder post is covered by a short hollow cylinder which extends to within one inch of the cap of the propeller-hub nut. The couplings of the stern and propeller shafts of the side engines, outside of the ship, are covered by water-tight, fair-water casings. The stern and propeller shafts are cased with brass in the stern tubes and bearings. The axial holes of all shafting are $7\frac{1}{2}$ inches in diameter, except at the outer ends of the propeller shafts, where the hole is tapered from $7\frac{1}{2}$ to $4\frac{1}{2}$ inches at the propeller, and remains the latter size throughout the length of the nut; and at the tapered ends of those shafts which are fitted to the socket couplings, where the hole is tapered from $7\frac{1}{2}$ to 6 inches in diameter. The axis of the center shaft is parallel to the base line, while the plane through the axes of the side shafts rises from the engines, making an angle of $1°12'$ with the base line. The angle between the axes of the side shafts is $4°46'$, making the inclination of each side shaft about twice as great outward as upward. The thrust bearings are of the collar-thrust style, lined with white metal. A bearing is fitted at each end of the pedestal to support the weight of the shaft, so that the collars bear only on the thrust surfaces, and an oil trough is made

of the bottom of the pedestal, and stuffing boxes fitted around the shaft to retain the oil. The cranks of each engine are set 120° apart, and in going ahead the sequence is H.P., I.P., L.P. The crank-shaft bearings have no top brasses, their places being filled by the caps, which are lined with white metal.

	Port and starboard.	*Center.*
Diameter of extension shaft, inches	16	.....
Lengths of extension shaft, inches	16½	.....
Diameter of crank shaft, inches	16	16
Length of each section of crank shaft, feet and inches	9–7½	9–7½
Diameter of crank pins, inches	17	17
Diameter of hole in crank pins, inches	8½	8½
Length of crank pins, inches	21½	21½
Number of crank-shaft bearings	6	6
Total length of crank-shaft bearings (one engine), inches	81	81
Width of crank webs, inches	18	18
Thickness of crank webs, inches	10¼	10¼
Diameter of eccentric seatings, inches	17	17
Diameter of flanges of crank shafts and connecting flanges, inches	27	27
Diameter of all other shaft flanges, inches	31	31
Thickness of flanges of all shafting, inches	3⅝	3⅝
Number of coupling bolts of all shafting, one flange	6	6
Diameter of straight coupling bolts, inches	3½	3½
Diameters of coupling bolts forward end of thrust shaft, inches	3½ and 4	3½ and 4
Diameter of line shaft, inches	15¾	
Length of line shaft, feet and inches	10–3	
Diameter of forward line shaft, inches		16
Length of forward line shaft, feet		3
Diameter of thrust shaft, inches	15¾	15¾
Length of thrust shaft, feet and inches	19–9⅜	29–2¼
Diameter of thrust collars, inches	23¼	23¼
Number of thrust collars	11	11
Actual thrust surface (one shaft), square inches	2,527	2,527
Thickness of thrust collars, inches	2	2
Width of space between thrust collars, inches	3¾	3¾
Diameter of after line shaft, inches		15¾
Length of after line shaft, feet and inches		18–4
Diameter, outside, of socket coupling, inches	30½	30
Diameter, inside, at bottom of taper, inches	14½	14½
Thickness of screw collar on shaft at socket coupling, inches	5½	5½
Number of collar bolts	6	6

	Port and Starboard.	*Center.*
Diameter of collar bolts, inches	2¾	2¾
Diameter of stern shaft, inches	15¾	
Diameter of propeller shaft, inches	16	16
Length of stern shaft, feet and inches	35–1	
Length of propeller shaft, feet and inches	38–10½	34–7
Diameter of shaft at propeller nut, inches	11	11
Depth of propeller nut, inches	11	11
Size of propeller keys, inches	2¼ × 4 × 33	2¼ × 4 × 33
Length of shafting over all, feet and inches	132–6⅝	113–1¾
Length of casing in stern tube, feet and inches	25–11½	23–10½
Length of bearings in stern tube, ft. and ins... Forward.	3–9	3–9
Length of bearings in stern tube, ft. and ins... Aft.	5	5–2½
Length of bracket bearings, feet and inches	5–2½	

Main Condensers.—There are three main condensers, one in each engine room, made of cast composition and bolted together in five sections. Each condenser has at either end a nozzle for the attachment of one of the two main exhaust pipes. The tubes are horizontal and the circulating water passes through them.

Length over all, feet and inches	14–9
Diameter of shell, inside, feet and inches	6–7
Thickness of shell, inch	½
Length of tubes exposed, feet and inches	11–10
Diameter of tubes, outside, inch	⅝
Thickness of tubes, No. 20, B.W.G., inch	0.035
Number of tubes, one condenser	4,894
Cooling surface, one condenser, square feet	9,475.75
Ratio of cooling surface of three condensers to heating surface of eight boilers	1 to 1.522
Ratio of cooling surface of three condensers to heating surface of ten boilers	1 to 1.591

Main Air Pumps.—There are three main air pumps of the well-known Blake vertical twin type, similar in all respects to those of the *New York*, of which an illustration is given at page 622 of the JOURNAL for 1893. Each pump has two single-acting water pistons driven by a pair of overhead steam cylinders. The pump rods and piston rods are secured to cross-heads, which are connected by swinging links to a working beam, from which the valve motion is actuated. These pumps have

been run as slowly as eight double strokes per minute, and have given eminent satisfaction at all speeds.

Diameter of steam cylinders, inches	16
Diameter of pump cylinders, inches	31½
Stroke, inches	21
Diameter of piston rods, inches	3
Diameter of pump rods, inches	5
Number of foot valves, each pump cylinder	19
Number of bucket valves, each pump cylinder	15
Number of delivery valves, each pump cylinder	18
Area of openings in each valve seat, square inches	13
Ratio of volume swept by L.P. piston, per stroke, to that of two air-pump buckets, per stroke	8 60 to 1

Main Circulating Pumps.—There are two centrifugal circulating pumps for each main condenser, driven by two vertical steam engines which stand between the pumps. The pumps are arranged to draw from the sea, from the main drainage pipe, and from the bilge of their own engine rooms, and are capable of discharging 6,750 gallons per minute. The sea and bilge injection valves are fitted with a self-locking arrangement which renders it impossible to have them both opened at once. The valves in the discharge pipe are so arranged that the bilge water is passed directly overboard instead of through the condenser.

Diameter of steam cylinders, inches	10
Stroke of steam cylinders, inches	6
Diameter of runner, inches	36
Diameter of casing, inches	42½
Width of casing, inches	8
Diameter of suction, inches	12¾
Diameter of discharge, inches	12

Screw Propellers.—The propellers are of the modified Griffith design, with three adjustable blades, and are made of manganese bronze. They are true screws when the blades are set at 20 feet 6 inches pitch. The pitch is variable between 19 feet 6 inches and 21 feet 6 inches. The blades are bent back about 15½ degrees from the vertical. The hubs are spherical and have conical tail pieces for the port and starboard propellers and a flat cap for the center one. The port propeller is left-handed and the other two right-handed.

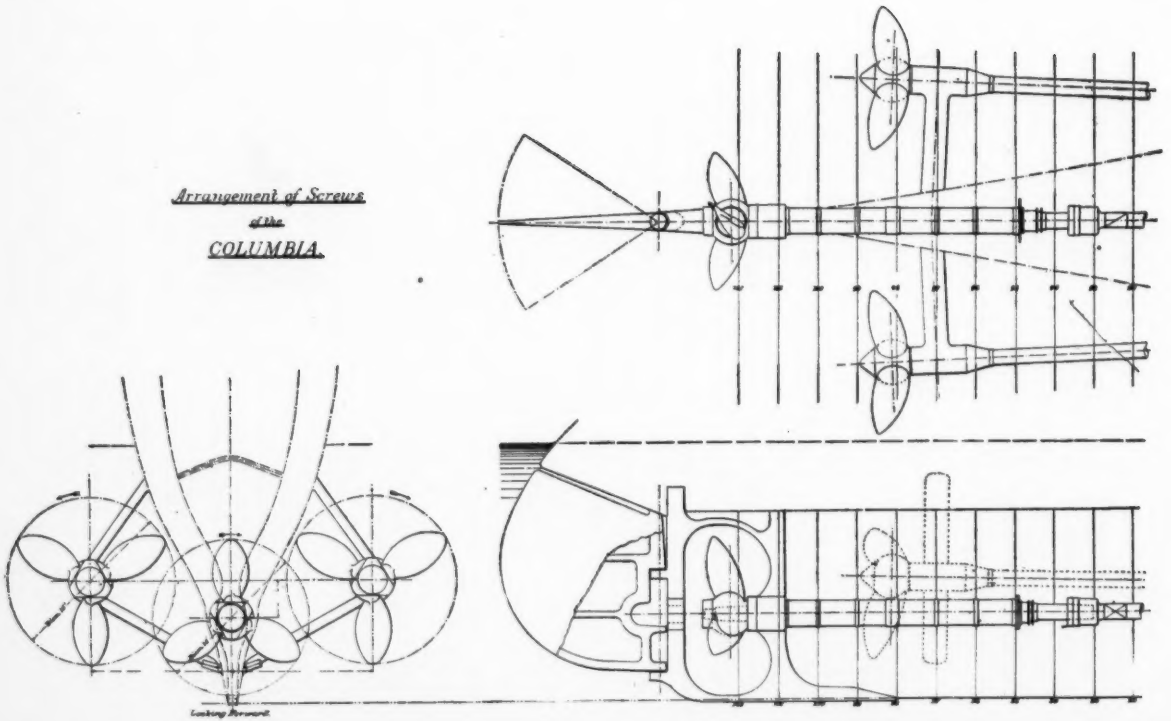
	Port and Starboard.	*Center.*
Diameter of propeller, feet	15.	14.
Diameter of hub, inches	59½	59½
Length of hub, inches	37.	37.
Length of end piece, inches	16.	10¼
Pitch, as set on trial, feet and inches	21–6	21–6
Helicoidal area for one propeller, square feet	53.7	53.28
Projected area for one propeller, square feet	41.25	40.2
Disc area for one propeller, square feet	176.715	153.938
Ratio of pitch to diameter	1.433	1.55
Distance of center of hub above bottom of keel, feet and inches	11–0	7–9
Immersion of center of hub at 24 feet draught, feet and inches	13–0	16–3
Ratio of disc area of three propellers to area of immersed midship section	0.419	
Distance between centers of hubs of side propellers, feet and inches	25–2½	
Distance, projected on a transverse plane, of centers of hubs of side propellers above center of hub of center propeller, feet and inches	3–3	
Distance, projected on a transverse plane, from center of hub of either side propeller to center of hub of center propeller, feet and inches	13–0¼	
Distance, projected on a longitudinal plane, of centers of hubs of side propellers forward of center of hub of center propeller, feet and inches	13–8	

BOILERS.

There are eight double-ended main and two single-ended auxiliary steel boilers of the horizontal fire-tube type. Each main boiler has eight, and each auxiliary boiler two corrugated furnaces. The main boilers are fitted fore-and-aft in pairs, in four water-tight compartments, and there are eight main fire rooms. The auxiliary boilers, which form part of the forced draft system, are located above the protective deck and stand athwartship between the branches of the uptakes from the ends of the main boilers; they are in two separate fire rooms, which are directly over the two after pairs of main boilers.

The shell of each main boiler is made up of three courses of three plates each; the circumferential seams are lapped and treble riveted, and the longitudinal seams have double butt straps

Arrangement of Screws
of the
COLUMBIA.



and are treble riveted, with every alternate rivet omitted in the outside row. The shell of each auxiliary boiler is in a single course, which is lapped and double riveted to the heads, the top sheets of which are curved to a radius of 2 feet $2\frac{1}{2}$ inches. The heads of the main boilers are in three sections and those of the auxiliary boilers in two. The furnaces are fitted with Cone's patent cast-iron rocking grate bars, which may be easily renewed while in use.

There are four main smoke pipes, 7 feet 8 inches in diameter, one for each pair of main boilers. The auxiliary smoke pipes, 2 feet 4 inches in diameter, are run up inside of the two after main smoke pipes.

The main boiler stop valves and safety valves can be operated from the berth deck. There is a 4-inch quadruple safety valve on each main boiler, and a 3-inch double safety valve on each auxiliary boiler. There is also one sentinel valve of $\frac{13}{16}$ inch diameter, of weight and lever pattern, on each boiler. The tops of the main boilers are two feet below the mean load line. The water in the boilers may be kept in circulation while raising steam by the use of Weir's hydrokineters, and also with the auxiliary feed pumps.

SIX MAIN BOILERS.

Length, feet	18
Diameter, outside, feet and inches	15–9
Number of furnaces	8
Diameter of furnaces, outside, inches	43
Diameter of furnaces, inside, inches	39
Length of grates, inches	78
Outside diameter of tubes, inches	$2\frac{1}{4}$
Length of tubes between sheets, inches	78
Spacing of tubes horizontally, inches	$3\frac{1}{2}$
Spacing of tubes vertically, inches	$3\frac{1}{4}$
Number of ordinary tubes	912
Number of stay tubes	316
Thickness of ordinary tubes, No. 12, B.W.G., inch	0.109
Thickness of stay tubes, No. 6, B.W.G., inch	0.203
Total number of tubes in one boiler	1,148
Number of combustion chambers	4
Depths of combustion chambers, inches	$24\frac{3}{8}$ and $25\frac{3}{32}$
Width of combustion chambers, feet and inches	6–$10\frac{7}{8}$

Thickness of shell plates, inches	$1\frac{21}{64}$
Thickness of heads, Top, inch	1
Thickness of heads, Bottom, inch	$\frac{3}{4}$
Thickness of tube sheets, front and back, inch	$\frac{5}{8}$
Thickness of combustion-chamber plates, inch	$\frac{9}{16}$
Thickness of furnaces, inch	$\frac{17}{32}$
Diameter of rivets in shell seams, inches	$1\frac{1}{8}$
Pitch of screw stays, inches	$7\frac{3}{4}$
Diameter of screw stays, inches	$1\frac{17}{64}$
Number and diameter of through braces above tubes, inches, (13)	$2\frac{3}{4}$
Number and diameter of through braces above tubes, inches, (10)	$2\frac{1}{2}$
Number and diameter of braces to back tube sheet, (16) inches	2
Number and diameter of braces around manholes, (17) inches	$1\frac{3}{4}$
Tube heating surface, one boiler, square feet	4,701.40
Plate heating surface, in furnaces, square feet	295.42
Plate heating surface, in combustion chambers, square feet	583.00
Total heating surface, square feet	5,579.82
Grate surface, square feet	168.
Ratio of grate surface to heating surface	1 to 33.213
Length of grate bars, feet and inches	6–6¾
Number of grate bars, one furnace	7
Area through tubes, square feet	26.82
Area over bridge walls, eight, square feet	16.37
Volume of furnaces and combustion chambers above grates, cubic feet	567.93
Steam room, water six inches above tubes, cubic feet	830.875
Water surface, water six inches above tubes, square feet	240.82
Diameter of smoke pipes, feet and inches	7–8
Area of three smoke pipes, net, square feet	129.94
Height of smoke pipe above lowest grates, feet and inches	72–6
Number and diameter of safety valves, in one case, inches (4)	4
Load on safety valves, pounds	160
Diameter of main-boiler stop valves, inches	10
Diameter of auxiliary stop valves, inches	5

TWO MAIN BOILERS.

Length, feet	18
Diameter, outside, feet and inches	15–3
Number of furnaces	8
Diameter of furnaces, outside, inches	43
Diameter of furnaces, inside, inches	39
Length of grates, inches	78
Outside diameter of tubes, inches	2¼
Length of tubes between sheets, inches	78
Spacing of tubes horizontally, inches	3½
Spacing of tubes vertically, inches	3¼
Number of ordinary tubes	784

Number of stay tubes	288
Thickness of ordinary tubes, No. 12, B. W. G., inch	0.109
Thickness of stay tubes, No. 6, B. W. G., inch	0.203
Total number of tubes in one boiler	1,072
Number of combustion chambers	4
Depth of combustion chambers, inches	$24\frac{3}{4}$–$25\frac{3}{32}$
Width of combustion chambers, feet and inches	6–$7\frac{5}{8}$
Thickness of shell plates, inches	$1\frac{13}{64}$
Thickness of heads, inch: Top	1
Thickness of heads, inch: Bottom	$\frac{3}{4}$
Thickness of tube sheets, front and back, inch	$\frac{5}{8}$
Thickness of combustion chamber plates, inch	$\frac{9}{16}$
Thickness of furnaces, inch	$\frac{17}{32}$
Diameter of rivets in shell seams, inches	$1\frac{1}{4}$
Pitch of screw stays, inches	$7\frac{3}{4}$
Diameter of screw stays, inches	$1\frac{17}{64}$
Number and diameter of through braces above tubes, inches: (11)	$2\frac{3}{4}$
Number and diameter of through braces above tubes, inches: (10)	$2\frac{1}{2}$
Number and diameter of through braces above tubes, inches: (2)	2
Number and diameter of braces to back tube sheet, inches: (12)	2
Number and diameter of braces to back tube sheet, inches: (9)	$1\frac{3}{4}$
Number and diameter of braces around manholes, inches (15)	$1\frac{3}{4}$
Tube heating surface, one boiler, square feet	4,104.15
Plate heating surface, in furnaces, square feet	295.42
Plate heating surface, in combustion chambers, square feet	495.04
Total heating surface, square feet	4,894.61
Grate surface, square feet	168.
Ratio of grate surface to heating surface	1 to 29.135
Length of grate bars, feet and inches	6–$6\frac{3}{4}$
Number of grate bars, one furnace	7
Area through tubes, square feet	23.00
Area over bridge walls (8), square feet	16.37
Volume of furnaces and combustion chambers above grates, cubic feet	549.05
Steam room, water six inches above tubes, cubic feet	633 96
Water surface, water six inches above tubes, square feet	230.48
Diameters of smoke pipe, feet and inches	7–8
Area of smoke pipe, two boilers, square feet	46.164
Height of smoke pipe above lowest grates, feet and inches	72–6
Number and diameter of safety valves in one case (4), inches	4
Load on safety valves, pounds	160
Diameter of main boiler stop valves, inches	10
Diameter of auxiliary stop valves, inches	5

TWO AUXILIARY BOILERS.

Length, feet and inches	8–6
Diameter outside, feet and inches	10–$1\frac{3}{32}$

Number of furnaces	2
Diameter of furnaces outside, inches	37
Diameter of furnaces inside, inches	33
Length of grates, inches	70
Outside diameter of tubes, inches	$2\frac{1}{2}$
Length of tubes between sheets, feet and inches	5–$8\frac{1}{2}$
Spacing of tubes horizontally, inches	$3\frac{3}{4}$
Spacing of tubes vertically, inches	$3\frac{3}{4}$
Number of ordinary tubes	158
Number of stay tubes	58
Thickness of ordinary tubes, No. 12, B.W.G., inch	0.109
Thickness of stay tubes, No. 6, B.W.G., inch	0.203
Total number of tubes in one boiler	216.
Number of combustion chambers	2.
Depths of combustion chambers, inches	$23\frac{1}{4}$ and $24\frac{3}{4}$
Width of combustion chambers, feet and inches	4–$1\frac{3}{4}$
Thickness of shell plates, inch	$\frac{27}{64}$
Thickness of heads, inch: Top	$\frac{27}{64}$
Thickness of heads, inch: Bottom	$\frac{3}{4}$
Thickness of tube sheets, front and back, inch	$\frac{3}{4}$
Thickness of combustion chamber plates, inch	$\frac{1}{2}$
Thickness of furnaces, inch	$\frac{15}{32}$
Diameter of rivets in shell seams, inch	1
Pitch of screw stays, inches	7
Diameter of screw stays, inches	$1\frac{9}{64}$
Number and diameter of through braces above tubes, inches	(8) 2
Number and diameter of braces to back tube sheet, inches: (2)	$1\frac{9}{16}$
Number and diameter of braces to back tube sheet, inches: (2)	2
Number and diameter of braces around lower manhole, inches: (1)	$1\frac{3}{4}$
Number and diameter of braces around lower manhole, inches: (2)	$1\frac{9}{16}$
Tube-heating surface, one boiler, square feet	824.67
Plate-heating surface in furnaces, square feet	55.40
Plate-heating surface in combustion chambers, square feet	96.25
Total heating surface, square feet	976.32
Grate surface, square feet	32.
Ratio of grate surface to heating surface	1 to 30.51
Length of grate bars, feet	6
Number of grate bars, one furnace	6
Area through tubes, square feet	8.25
Area over bridge walls (2), square feet	3.91
Volume of furnaces and combustion chambers above grates, cubic feet	94.66
Steam room, water six inches above tubes, cubic feet	114.02
Water surface, water six inches above tubes, square feet	72.19
Diameters of smoke pipes, feet and inches	2–4
Area of smoke pipe, square feet	4.276
Height of smoke pipe above grates, feet and inches	54–10

Number and diameter of safety valves (2), inches	3
Load on safety valves, pounds	160
Diameter of stop valves, inches	5

TOTALS FOR BOILERS.

	8 Main.	*10 Boilers.*
Tube heating surface, square feet	36,416.69	38,066.03
Plate heating surface, in furnaces, square feet	2,363.36	2,474.16
Plate-heating surface, in combustion chambers, square feet	4.448.08	4,680.58
Total heating surface, square feet	43.268.13	45,220.77
Grate surface, square feet	1.344.	1,408.
Area through tubes, square feet	206 92	223.42
Area over bridge walls, square feet	130.96	138.78
Volume of steam room, cubic feet	6,253.17	6,481.21
Area of water surface, square feet	1.905.88	2,366.84
Volume of combustion chambers and furnaces above grates, cubic feet	4.505.68	4,695.00
Weight of boilers with fittings and water per 100 square feet of heating surface, tons	2.31	2.33
	4 After Main.	*2 Auxiliary.*
Tube-heating surface, square feet	18,805.60	1,649.34
Plate-heating surface, in furnaces, square feet	1,181.68	110.80
Plate-heating surface, in combustion chambers, square feet	2,332.00	192.50
Total heating surface, square feet	22,319.28	1,952.64
Grate surface, square feet	672.	64.
Area through tubes, square feet	107.28	16.5
Area over bridge walls, square feet	65.48	7.82
Volume of steam room, cubic feet	3,323.5	228.04
Area of water surface, square feet	963.28	460.96
Volume of combustion chambers and furnaces above grates, cubic feet	2,271.72	189.32
Ratios:	*8 Main.*	*10 Boilers.*
Tube H.S. to G.S.	26.70 to 1	26.66 to 1
Plate H.S. in furnaces to G.S	1.733 to 1	1.733 to 1
Plate H.S. in combustion chambers to G.S.	3.290 to 1	3.278 to 1
Total H.S. to G.S	31.722 to 1	31.667 to 1
Area through tubes to G.S	0.152 to 1	0.156 to 1
Area of water surface to G.S	1.40 to 1	1.66 to 1
Volume of steam room per square foot G.S	4.58 to 1	4.54 to 1
Volume of combustion chambers and furnaces above grates per square foot G.S.	3.25 to 1	3.29 to 1

Forced Draft.—Eighteen Sturtevant blowers are used to force air into the closed fire rooms, two for each main fire room and one for each auxiliary fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines, with cranks at 180°.

BLOWERS IN MAIN FIRE ROOMS.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan, inches	19
Area of induction nozzle, square inches	1,061
Area of eduction nozzle, square inches	2,827

BLOWERS IN AUXILIARY FIRE ROOMS.

Diameter of steam cylinders, inches	3½
Stroke, inches	2½
Diameter of fan, inches	36
Area of induction nozzle, square inches	520
Area of eduction nozzle, square inches	1,018

Ventilating Fans.—There are three fans for ventilating the main engine rooms, one for the evaporator room, and four for the living quarters of the ship, all of the same general style as the forced-draft blowers. Those for the port and starboard engine rooms have engines with cylinders 4 inches diameter by 3 inches stroke, and that for the center engine room has engines 3½ inches diameter by 2½ inches stroke. The diameter and width of the fans for port and starboard engine rooms are 48 and 19 inches, and for the other fans the dimensions are 36 and 20 inches respectively. The areas of eduction nozzles of fans for port and starboard engine rooms, for center engine room, for evaporator room, and for the ship are, respectively, in area 1,810, 1,818, 396, and 440 square inches.

Auxiliary Condensers.—There are two Wheeler condensers, one in the port and one in the starboard engine room, connected with the auxiliary exhaust pipes. Each condenser has a combined air and circulating pump, the three pistons being on a single rod. The steam cylinder is 8, the air-pump cylinder 10, and the circulating-pump cylinder 10 inches in diameter, and the stroke is 12 inches. The cooling surface of each condenser is 680 square feet.

Feed Pumps.—In the main-boiler fire rooms there are four pumps for the main boiler-feed system, and also four others for the auxiliary feed system; and in each auxiliary-boiler fire room

there are two pumps, one for each of the above mentioned systems; making twelve feed pumps in the fire rooms. These pumps are all of Blake's make, vertical duplex. The eight pumps in the main fire rooms have steam cylinders 12 inches diameter by 12 inches stroke, and water cylinder $7\frac{1}{8}$ inches diameter by 12 inches stroke. The four pumps in the auxiliary feed system may be used for fire and bilge purposes and for pumping out the boilers. The four feed pumps in the auxiliary fire rooms have steam cylinders 6 inches diameter by 7 inches stroke, and water cylinders $4\frac{1}{8}$ inches diameter by 7 inches stroke, and the two of these that are part of the auxiliary feed system may be used on the fire mains. The capacity of these pumps is 100 gallons per minute each.

Feed, Fire and Bilge Pumps.—In each engine room there is a horizontal Blake duplex feed, fire and bilge pump, with steam cylinder 12 inches diameter by 12 inches stroke, and water cylinders $8\frac{1}{2}$ inches diameter by 12 inches stroke.

Fire and Bilge Pumps.—There are three Blake vertical, duplex fire and feed pumps, one in each engine room, having steam cylinders 14 inches diameter by 12 inches stroke, and water cylinder 9 inches diameter by 12 inches stroke.

Water Service and Fire Pumps.—For engine room water service and fire purposes there are three Blake vertical, duplex pumps, one in each engine room, with steam cylinders $7\frac{1}{2}$ inches diameter by 8 inches stroke, and water cylinders $4\frac{1}{2}$ inches diameter by 8 inches stroke.

The capacity of the auxiliary pumps is for fire purposes 2,750 gallons of water per minute, and for bilge discharge 2,300 gallons per minute.

Wrecking Pump.—On the port side of the evaporator room is one wrecking pump having a capacity of 1,000 gallons per minute. It is of Blake pattern with one steam and one water cylinder, the sizes of which are 12 inches diameter by 18 inches stroke and 16 inches diameter by 18 inches stroke, respectively.

Distilling Apparatus.—The evaporator room is on the protective deck, and surrounds the uptake to the second smoke pipe. In it are the wrecking pump and the distilling apparatus.

There are two No. 5 Baird distillers and two Type 6-C Baird evaporators, to which are fitted three Davidson steam pumps. The maximum distilling capacity is 12,600, and the ordinary capacity about 8,000 gallons per day. When connected to the condensers for supplying deficiency of feed water the estimated capacity is 10,000 gallons per day. A light-service pump supplies the cooling water for the distillers; its steam cylinder is 8 inches diameter and water cylinder 9 inches, with a common stroke of 12 inches. After leaving the distillers the water from this pump enters the flushing pipes, or may be directed into them without passing through the distillers, as by-pass valves and pipes are fitted for the purpose. There is a combined regular pressure pump, having one steam cylinder and two water cylinders, one for feeding the evaporators (brass $2\frac{1}{4}$ by 4 inches) and the other (iron $2\frac{1}{4}$ by 4 inches) for conveying the water from the filters to the ship's tanks. The steam cylinder is $3\frac{1}{2}$ by 4 inches. There is also a regular pressure pump for delivering the drain water to the feed tanks, the diameter of the steam cylinder being $3\frac{1}{2}$ inches and the stroke 4 inches, and the diameter of the water cylinder $2\frac{1}{4}$ inches.

Ice Machine.—There is an Allen dense-air machine capable of making 200 pounds of ice per day and at the same time keeping the refrigerating room near the freezing point and cooling 300 gallons of drinking water to 40 degrees Fahrenheit. It is equivalent to the use of one ton of ice per day. The diameters of the cylinders are as follows: Steam cylinder, 7 inches; air-compressor cylinder, $5\frac{3}{4}$ inches; air-expansion cylinder, $4\frac{3}{4}$ inches; all double acting and having a stroke of 10 inches. The water and primer pumps are single acting, each $1\frac{5}{8}$ inches diameter by 10 inches stroke.

Workshop.—The workshop is on the protective deck adjacent to the center engine room. It is fitted with a vertical engine, 4 by 5 inches, a shaping machine, a lathe, an emery grinder, a drill press, and other necessary tools.

Electrical Apparatus.—In the dynamo room there are duplicate generating sets, built at Schenectady, N. Y., by the General Electric Company. In each set there is a 32-kilo-watt dynamo of

the multipolar type, having an output of 400 amperes at 80 volts, compound wound on 110 armature sections, cross connected at 180 degrees. The engines are double-cylinder, vertical, inverted, the pistons being 13 inches in diameter and their stroke 6 inches. The crank shaft and armature shaft are common. The engines are designed to run at 400 revolutions under 80 pounds of steam with full load. On the steam pipe before it branches to the engines are a stop valve, a pressure-reducing valve and a steam separator. The bed plate, which is common to both engine and dynamo, measures 4 feet 7 inches by 8 feet 4 inches. The weight of each generating set (engine, dynamo and bed plate) is about 9,000 pounds. The switch board is a model of simplicity and compactness. It is of the Navy type, with 12 sections, 2 pairs of negative bus bars and one pair of positive bars. There are 490 (16-candle power) outlets, distributed throughout the ship. Of these 167 are in the engineer department, as follows: in the 53 coal bunkers, 10 fire rooms, and 3 engine rooms, 38, 72 and 55 lamps respectively. There are also three fixed and two portable lights in the steam steering room, and in addition to the above-mentioned 38 fixed lamps, the coal bunkers are lighted by portable lamps from the gun-deck circuits. There are electric side and mast-head lights; and for signal purposes at night there are ten 16-candle power signal lanterns, single, and a set of five Ardois 32-candle power double lanterns.

The dynamo room is ventilated by a blower, which delivers 2,250 cubic feet of air per minute when running at 1,500 revolutions; it is driven by a two-horse power motor. Two one-quarter-horse power portable motors are to be supplied to drive fans, each capable of delivering 400 cubic feet of air per minute at 1,800 revolutions.

There are two search lights of the Mangin type, mounted on special platforms at fore and main masts, and electrically controlled. The projectors are 30 inches in diameter, the lamps are hand or automatic, and the current is 90 amperes at 45 volts. The telegraphs, etc., are elsewhere mentioned. There are water alarms in each bilge compartment, and thermostats in each coal

bunker and paint room, with annunciators on the forward cabin bulkhead. The current distribution is as follows:

2 400-ampere generators		64,000 watts.
490 lights at 0.8 ampere	31,360 watts.	
2 search lights	14,400 "	
1 2-H.P. motor	1,480 "	
2 ¼-H.P. motors	370 "	47,610 watts.
Reserve power		16,390 watts.

Steam Launches.—There are two steam launches, one 30 feet and the other 33 feet long. They are fitted with Towne boilers, having steam jets for use only in emergencies. Keel condensers are attached to both launches. The cylinders of the 30-foot launch are 3½ by 7 by 6 inches, and the propeller is 27 inches diameter by 48 inches pitch. The cylinders of the 33-foot launch are 4 by 7 by 7 inches, and the propeller is 30 inches diameter by 48 inches pitch. The capacities of the water tank and coal bunkers of the 30 and 33-foot launches are, 80 and 110 gallons and 600 and 680 pounds respectively.

Other Auxiliary Machinery.—Situated in the fire-room hatches are eight Williamson ash-hoisting engines, having each two vertical cylinders of 4½ inches diameter by 4½ inches stroke. There is one ammunition-hoisting engine, of 5 inches diameter by 6 inches stroke, having two oscillating cylinders. There are three steam winches with double cylinders 8 by 8 inches, two of which are single and double geared, without drum, and one reversible with drum. There is one of the American Ship Windlass Co.'s windlass and capstan engines, with double cylinders, 12 inches diameter by 14 inches stroke. There is one of Williamson & Bros., combined hand and steam steering engines, with double cylinders 13 inches diameter by 10 inches stroke. It requires 70 revolutions to shift the helm from extreme starboard to extreme port.

From the foregoing detailed description, it will be seen that there are more separate engines in the *Columbia* than in any vessel that we have hitherto constructed, the largest number up to this time having been in the *New York*. For convenience of

reference, and to show at a glance the various purposes for which separate engines are used, all of them are grouped in the following list:

ENGINES ON BOARD THE COLUMBIA.

Engines.	*Steam Cylinders.*
3 main propelling engines, vertical, triple expansion	9
3 main air pumps, Blake, vertical, double	6
3 main circulating pumps, vertical, double	6
2 auxiliary air and circulating pumps, Blake, horizontal	2
4 main feed pumps, Blake, vertical, duplex	8
4 auxiliary feed pumps, Blake, vertical, duplex	8
3 auxiliary feed, fire and bilge pumps, Blake, horizontal, duplex	6
3 auxiliary fire and bilge pumps, Blake, vertical, duplex	6
2 main feed pumps for auxiliary boilers, Blake, vertical, duplex	4
2 auxiliary feed and fire pumps, in auxiliary-boiler rooms, Blake, vertical, duplex	4
3 fire and bilge pumps, Blake, vertical, duplex	6
3 water-service pumps, main engines, Blake, vertical, duplex	6
1 oil pump, Blake, horizontal, duplex	2
3 reversing engines, single	3
3 turning engines, vertical, double	6
18 forced-draft blowers, Sturtevant, vertical, double	36
3 ventilating blowers, Sturtevant, for engine rooms, vertical, double	6
1 ventilating blower, Sturtevant, for evaporator room, vertical, double	2
4 ventilating blowers, Sturtevant, for ship, vertical, double	8
8 ash-hoisting engines, vertical, double	16
3 evaporator and distiller pumps, Davidson, single	3
1 workshop engine, vertical, single	1
2 dynamo engines, vertical, double	4
1 steering engine, Williamson, horizontal, double	2
1 wrecking pump, Blake, horizontal, single	1
1 windlass and capstan engine, American Ship Windlass Co., vertical, double	2
3 winches, Williamson, horizontal, double	6
1 ammunition-hoisting engine, oscillating, double	2
1 ice machine, Allen's dense-air, horizontal	1
2 steam-launch propelling engines, vertical, compound	4
2 steam-launch feed pumps, vertical, double	4
94 Total	180

Coal Bunkers.—The total capacity of the coal bunkers is 1,696 tons. There are 53 bunkers, 31 below the protective deck and 22 above it, holding 969 and 727 tons of coal, respectively. There is a complete and convenient overhead railway for transporting coal from the bunkers to the fire rooms, the buckets being constructed so as to dump easily.

Drainage System.—There are two pipes for pumping and draining, extending throughout the length of the boiler and engine compartments, a 12-inch main pipe on the port side and a 7-inch secondary pipe on the starboard side, each of which has a branch in each main fire and engine room leading to a cistern. These pipes are fitted with screw-down non-return valves, which may be operated from above the protective deck. The compartments outside of the boiler and engine spaces are connected with valve boxes within the fire and engine rooms. There are two auxiliary pumps in each engine room that have connections to the secondary pipe; and the four pumps in the main fire rooms which form a part of the auxiliary boiler-feed system are also connected with this pipe and to the bilge of their own compartments as well. The wrecking pump is connected with the main drainage pipe. One of the two centrifugal pumps in each engine room is connected with the bilge direct, and the other pump is fitted to draw from the main drainage pipe. The two drainage pipes are cross connected in one of the fire rooms by a pipe and valve. There are two manifolds in the starboard and one in the port engine room, connected with the double-bottom compartments and with the auxiliary pumps in the engine rooms. The double-bottom compartments may be flooded through the sea valves and the suction manifolds, and they are supplied with vent pipes, which extend above the living spaces of the ship.

Communication, Revolution Indicators, etc.—The systems of communication between the different parts of the ship are very complete. Telephones will connect the Captain's cabin with the pilot house, and the executive officer's office with the master-at-arms' station. The system of voice tubes with call bells is both simple and complete. For general purposes a central transmitting station is used, which vastly lessens the number of tubes required to give the same service. For connecting the most important stations, however, direct tubes are fitted, which do not go to the central station. The center engine room is connected with the others, to the ten fire rooms, and to various other parts of the engineer department by voice tubes and call bells. There are three Cory mechanical telegraphs on the bridge,

and the same number in the pilot house and in the conning tower, one of which at each station is in communication with another situated in one of the main engine rooms. These telegraphs are so connected that the shifting of either one of the four forming a set shifts the other three. There is a mechanical gong in each engine room connected with bell pulls at the steering wheels on the after part of the bridge deck, and there is a mechanical gong for each of the eight ash hoists. There are mechanical tell tales from each engine room to the bridge, pilot house and conning tower, to show when and in which direction the main engines are turning. Electrical speed indicators and transmitters have also been fitted; also electrical helm indicators. In the port and starboard engine rooms there are two mechanical indicators to denote the speed and direction of revolution of the side engines. The two indicators are connected and each has two hands of different colors, a red one which turns with the port and a green one which turns with the starboard engine. These hands may be turned on their shafts, like the hands of a clock, and by setting the two together an indication is at once given of the relative speeds of the side propellers, as the hands separate or remain together in their revolutions over the dial of the indicator. The hands make one revolution for one hundred of the engine.

WEIGHTS.

Propelling machinery, including water, tons	1,934.04
Reciprocating parts:	
H.P. piston, pounds	1,449
I.P. piston, pounds	2,414
L.P. piston, pounds	5,849
3 piston rods with nuts, pounds	4,766
3 cross heads, pounds	5,563
3 connecting rods, pounds	19,467
Most important detailed weights, general:	
8 main boilers, complete with attachments, pounds	1,579,351
Water in same (6 inches above combustion chamber), pounds	669,972
2 auxiliary boilers, complete with attachments, pounds	74,080
Water in same (6 inches above combustion chambers), pounds	37,260
Water, fresh in feed pumps and pipes, pounds	4,652
Water, fresh, in air pumps and pipes, pounds	22,163
Water, salt, in condensers and connections, pounds	44,172

Water, salt, in stern tubes, pounds	3,848
Boiler safety-valve gear, pounds	5,090
Uptakes of main boilers, pounds	128,812
Uptakes of auxiliary boilers, pounds	4,130
4 main smoke pipes, pounds	70,829
Escape pipes, pounds	6,210
Whistle and siren, pounds	332
Receiver pipes and fittings (three engines), pounds	14,199
Feed pipes and fittings, pounds	6,025
Auxiliary steam and exhaust pipes, pounds	14,650
Other copper pipes, pounds	63,852
Main steam pipes, pounds	42,504
10 stop valves, main steam pipes, pounds	13,032
3 steam separators, pounds	2,187
Gauges, counters, etc., pounds	698
12 boiler feed pumps, pounds	27,264
Oil service, pounds	4,067
18 blowers and blower engines, pounds	22,252
Distillers and fittings, pounds	6,227
Evaporators, pounds	11,485
Steam traps, pounds	2,418
4 grease extractors, pounds	3,454
8 ash-hoisting engines, pounds	19,490
Ash railway, pounds	1,222
Floor plates, gratings, etc., pounds	56,035
The following are for one engine room only:	
Bed plate, pounds	46,269
6 engine columns, pounds	8,627
3 engine frames, pounds	23,725
10 tie rods, pounds	3,164
Drain cocks and gear, cylinders and valve chests, pounds	421
10 stuffing boxes, piston rods and valve stems, pounds	1,711
7 piston valves, pounds	5,593
Valve stems, crossheads and guides, pounds	2,941
8 eccentrics and straps, pounds	8,204
8 eccentric rods, pounds	2,355
4 links, pounds	2,087
Reversing shafts and brackets, pounds	7,412
Steam reversing engine, pounds	2,962
Oil pump, hand reversing gear, pounds	441
Crank shaft, pounds	28,518
Line shaft, pounds	6,360
Thrust shaft, pounds	14,378
Stern shaft, pounds	24,305
Propeller shaft, pounds	24,654
Coupling bolts for shafting, pounds	1,742

Propeller, pounds	18,632
Friction brake, pounds	820
2 line-shaft bearings, pounds	2,874
1 thrust-shaft bearing, pounds	14,013
1 stern bearing, pounds	3,396
1 strut bearing, pounds	1,735
Indicator pipes and fittings, pounds	106
Turning engines, pounds	4,882
Throttle and butterfly valve and gear, pounds	2,947
Water service, pounds	1,928
Main condenser, pounds	27,235
Auxiliary condenser, pounds	7,223
Feed tank, pounds	5,252
Main air pumps and engines, pounds	17,233
Circulating pumps and engines, pounds	6,794
1 fire and bilge pump, pounds	3,825
1 fire and water-service pump, pounds	1,290
1 fire and feed pump, pounds	3,816

THE TRIALS.

There were two official trials, one to determine the speed under the conditions of the contract, and another to ascertain the coal consumption with the air pressure existing in the fire rooms during the contract or speed trial.

The *Columbia* sailed from Philadelphia, November 11, 1893, for Boston, Mass., using all the main boilers and three engines, making the run from the light ship off Cape Henlopen to Minot's Ledge, a distance of 407.4 knots, in 21 hours 52 minutes, or at the rate of 18.63 knots per hour. The engines averaged 112 revolutions per minute, with a steam pressure of 125 pounds, developing about 12,000 H.P. The mean draught of water on leaving Cape Henlopen was 23 feet 10 inches, and on arrival at Boston it was 22 feet 9 inches.

After giving the crew a rest of a day and night the ship was, on November 14th, run over the trial course with all boilers in service in one direction under natural draft, the average speed being 20¾ knots per hour, and in the other under forced draft. On the latter run the vessel made the 7.74 knots between two of the buoys at the apparent rate of 24.9 knots an hour, the engines averaging 138 revolutions per minute. But as will be seen from an examination of the two official runs hereafter given, one

of the buoys—the one opposite the *Fortune*—had evidently either been inaccurately placed, or had drifted towards the *Vesuvius* in the direction of the course, as the apparent speed going in each direction was much above the average between these buoys, and much below it between the *Fortune* and the *Narkeeta*.

After this run the boiler safety valves were reset, under the inspection of the Board of Naval Engineers, to blow at 168 pounds, 160 pounds plus 5 per cent., two gauges that had been standardized at the New York Navy Yard being used for the purpose. These gauges were left attached to the after pair of main boilers. It was found that the gauges supplied generally indicated the pressure too high. After the return of the ship to the works of the contractors all of the steam gauges were compared and corrections applied to the recorded readings.

On November 16th, after a good rest for the crew, the ship attempted the contract trial, but had to abandon it, as the weather was such that the guide vessels could not remain at an anchor on the course.

After the crew had had another rest, the contract trial took place on November 18th.

On November 19th the ship left Boston, and arrived at Philadelphia the following day, having made the passage with two engines. When nearing the Delaware Capes the ship was for several hours in a northwest gale, during which time she behaved well, though the engines raced.

The ship vibrates a great deal when the engines are making between 90 and 100 revolutions per minute, but above that speed the vibrations are greatly lessened, and below it the vessel is steady. During these trials the contractors had in the fire and engine rooms a highly skilled crew, probably the best ever gotten together in this country, and they did not consider that their men could perform satisfactory work after a few hours of steaming at full speed. The Government, unfortunately, has not at its command, sufficient men to run its fine ships at fast speeds for longer than short periods. The allowance of men for the engineer department of the *Columbia* is 196, out of which the cooks for the firemen's messes must be taken. It is interesting

to note the difference in complement between regular commission and a contract trial, the numbers in each case being given in detail below:

12 machinists		
1 yeoman,		8 machinists,
1 coppersmith,	Will tend	54 oilers,
3 boiler-makers,	water when	18 water tenders,
1 blacksmith,	steaming.	60 firemen,
8 water tenders,		6 boiler-makers,
15 oilers,		6 riggers,
35 first-class firemen,		80 coal passers,
35 second-class firemen,		
85 coal passers,		
196	Total	232

CONTRACT TRIAL.

The contract trial occurred November 18, 1893, over the course, 43.968 knots in length, extending from Cape Ann, Massachusetts, to Cape Porpoise, Maine. The course was accurately marked by a line of buoys, and a vessel was anchored close to each buoy as a marker and for taking tidal observations. The weather conditions were favorable. The vessel ran over the course from Cape Ann up, and after making a large turn, and without slowing of the engines, returned over the same course, the distance between buoys, the time and the mean speed being as follows:

Run North.

Station vessel.	Distance.	Elapsed time. *m. s.*	Speed.
Dolphin, . .	. .	. .	. .
Iwana, . .	2.37	6–16	22.69
Kearsarge, . .	6.66	18–3	22.14
Leyden, . .	6.66	17–18	23.10
Fern, . . .	6.40	16–16	23.55
Narkeeta, . .	6.40	17–16	22.24
Fortune, . .	7.74	21–36	21.50
Vesuvius, . .	7.74	18–21	25.30

Total time on course of 43.968 nautical miles, 1 hour 55 minutes 6.1 seconds; mean speed for the run, 22.92 knots.

Run South.

Vesuvius,	. .	. .	. .
Fortune,	7.74	18–45	24.77
Narkeeta,	7.74	22–0	21.11
Fern,	6.40	17–45	21.63
Leyden,	6.40	16–11	23.73
Kearsarge,	6.66	17–24	22.96
Iwana,	6.66	17–53	22.34
Dolphin,	2.37	6–16	22.69

Total time on course, 1 hour 56 minutes 14.4 seconds; mean speed for the run, 22.70; mean apparent speed for both runs, 22.81 knots.

From this mean speed a deduction of .01 knot was made for the tidal correction, thus giving 22.8 knots as the official speed of the ship.

The mean apparent speed over the several divisions of the course, in each direction, calling that between the *Dolphin* and *Iwana* No. 1, and that between the *Fortune* and the *Vesuvius* No. 7, is as follows:

	Run North.	*Run South.*
No. 1,	22.69	22.69
No. 2,	22.14	22.34
No. 3,	23.10	22.96
No. 4,	23.55	23.73
No. 5,	22.24	21.63
No. 6,	21.50	21.11
No. 7,	25.30	24.77

From this it would appear that the *Fortune* had drifted towards the *Vesuvius*, and the *Fern* towards the *Leyden*, though the movement in the latter case must have been quite small, if there was any at all.

Twenty officers of the Engineer corps of the Navy were on board to watch the performance of the boilers and machinery, and to take the desired data relative thereto. The operation of the machinery was in every way satisfactory, except the warming of one crosshead journal during the first part of the trial, and

the irregularities consequent on the foaming of the boilers several times during the down run. Water was carried over into the cylinders of the port and center engines at 12.35 and again at 12.50 P. M., causing a slowing of these engines, notably of the former. The two auxiliary condensers were in operation during the trial. As a precaution, small streams of water were kept running on some of the journals, and oil was used very freely throughout the trial.

Indicator diagrams were taken from the main cylinders on crossing the lines at the beginning and end of each run over the course and at intermediate intervals of thirty minutes, and from the principal auxiliary engines once an hour. The indicated horse power given below for the main engines is the average of ten sets of diagrams. The eight main and two auxiliary boilers were in use until 1.40 P. M., thirty minutes before the end of the trial, when the auxiliaries were disconnected and thereafter only the steam from the main boilers was used. With the exceptions noted, the engines ran with extreme smoothness and marked absence of heating of working parts, which was largely due to the superior workmanship on the part of the contractors, who were urged to do their best in the hope of earning a large premium; and they succeeded in obtaining $350,000, the largest premium ever paid in case of any of our naval vessels.

The condition of the machinery at the end of the trial was such that the trial could have been at once repeated, and probably with better results. Subsequent examination showed the boilers and engines to be in excellent condition.

The untrustworthiness of the patent log was clearly shown on this trial. The up run was made with two logs and the down run with one, the other having been carried away; the mean of the readings of both logs in one direction over the course and the reading of one log on the return run gave the length of the course as being 46.98 knots, or the average speed of the *Columbia* was by patent log 24.34 knots, a point worth bearing in mind when one reads of the performances of foreign ships, the speeds of which for runs off the measured mile are usually recorded by patent log.

The small amount of horse power required to give the speed of the contract trial can only be due to its application to three screws and to the fine lines of the hull. Very little wave is made by the vessel at high speeds, as will be noticed in the illustration given herewith. The wake is not much different from that of fast twin-screw vessels.

The *Columbia's* performance is more remarkable than is generally known. She not only made a phenomenal speed, but did it with such marked economy as to lead to the belief that triple screws are a better method of applying power than twin screws and it would not be surprising to see triple screws adopted for use on large, fast merchant steamers in the near future.

DATA OF THE CONTRACT TRIAL.

Draught, on trial, feet and inches	forward	21–3
	aft	23–8
	mean	22–5
Displacement at mean draught on trial, tons		7,350
Area of immersed midship section, square feet		1,120
Wetted surface (by calculation), square feet		27,590
I.H.P. (total), per 100 square feet of wetted surface		67.09
I.H.P. per 100 square feet of wetted surface at 10 knots, reduced in ratio of power		3.75
Average speed, knots		22.8
Speed^3 × area immersed midship section ÷ I.H.P.		740.8
Speed^3 × displacement $^{\frac{2}{3}}$ ÷ I.H.P.		249.6

SYNOPSIS OF STEAM LOG.

		Port.	*Center.*	*Starboard.*
Slip of screws, per cent		19.13	15.85	19.82
Slip (mean of three screws), per cent			18.27	
Revolutions of main engines, per minute		132.9	127.68	134.
Revolutions, mean of three engines			131.72	
Piston speed, feet per minute		930.3	893 76	938.
Steam pressure at boilers, per gauge, pounds			147.2	
Steam pressure at engine, per gauge, pounds		145 5	144.	145.
Steam pressure at first receiver, absolute, pounds,		62.	63 5	75.
Steam pressure at second receiver, absolute, pounds		25.4	22.7	29.2
Vacuum in condenser, in inches of mercury		25.6	25.	25.1
Barometer		29.78	29.78	29.78
Opening of throttle in tenths		10.	10.	10.
Steam cut off in fraction of stroke from beginning	H.P.	.7	.6	.6
	I.P.	.7	.7	.7
	L.P.	.7	.7	.7

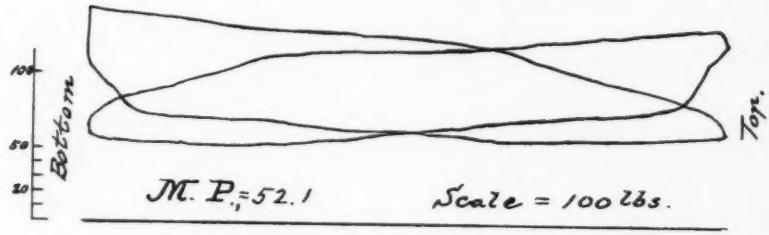
	Port.	*Center.*	*Starboard.*
Temperature of engine room	75.4	87.	84.
Temperature of injection water	49.	49.	49.
Temperature of discharge water	115.8	118.	134.2
Temperature of feed water	100.	115.	109.3
Temperature of fire rooms		105.7	
Air pressure, in inches of water, in fire rooms		.73	
Revolution of blowers per minute—Main fire rooms		360.5	
Revolution of blowers per minute—Auxiliary fire rooms		496.4	
Revolution of blowers per minute—Engine rooms		500.	
Revolutions of main circulating pumps per minute	144.	123 6	151.7
Double strokes of main air pumps per minute	13.9	14.4	17.
Velocity of steam in feet per second, at maximum opening of valves through—			
Main steam pipe	121.52	116.76	122.53
Main exhaust pipe	129.62	127.42	130.68
H.P. steam ports	103.13	102.42	107.48
I.P. steam ports	140.83	135.30	141.99
L.P. steam ports	198.60	190.79	200.23
H.P. exhaust ports	103.64	99.57	109.42
I.P. exhaust ports	110.10	106.02	111.012
L.P. exhaust ports	134 38	129.10	135.49
Corrected mean effective pressure in—			
H.P. cylinder	51.57	56.25	55.63
I.P. cylinder	26.00	25.19	29.54
L.P. cylinder	12.60	11.55	14.73
Mean pressure on L.P. piston, equivalent to aggregate M.E.P. on all pistons	29.78	32.48	35.09
Indicated horse power of—			
H.P. cylinder	1,724.84	1,747.34	1,922.17
I.P. cylinder	1,861.18	1,770.56	2,159.07
L.P. cylinder	1,973.65	2,307.70	2,524.60
Collective I.H.P. of each main engine	5,559.67	5,825.60	6,605.84
Collective I H.P. of three main engines		17,991.11	
I.H.P. of main circulating-pump engines	14.073	6.997	8.674
I.H.P. of main air-pump engines	16.299	17.973	22.170
Collective I.H.P. of main circulating-pump engines		29.744	
Collective I.H.P. of main air-pump engines		86.186	
I.H.P. of two auxiliary air and circulating pumps		4.109	
I.H.P. of three fire and water-service pumps		11.597	
I.H.P. of three fire and bilge pumps		22.159	
I.H.P. of three fire, feed and bilge pumps		3 397	
I.H.P. of six main-boiler feed pumps		178 380	
I H.P. of two auxiliary-boiler feed pumps (estimated)		13.000	

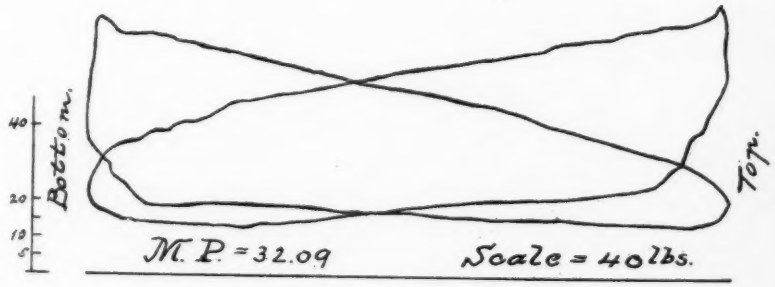
	Port.	*Center.*	*Starboard.*
I.H.P. of sixteen blower engines in main fire rooms		154.304	
I.H.P. of two blower engines in auxiliary fire rooms (estimated)		12.000	
I.H.P. of two blower engines in engine rooms (estimated)		5.000	
I.H.P. of dynamo engine (estimated)		28.000	
Collective I.H.P. of all auxiliary engines in use		518.132	
Collective I.H.P. of each main engine, air and circulating pumps	5,590.042	5,850.570	6,636.684
Collective I.H.P. of all main engines, air and circulating pumps		18,077.296	
Total I.H.P. of all machinery in use		18,509.242	
Indicated thrust (main engines only), pounds	64,209.53	70,031.50	75,665.64
Indicated thrust, per square foot of developed area of propeller, pounds	1,195.71	1,314.41	1,409.04
Indicated thrust per square inch of thrust bearing, pounds	25.41	27.71	29.94
Cubic feet swept per minute by L.P. piston per I.H.P.	7.72	7.08	6.56
Square feet of cooling surface per I.H.P. (main engines)	1.704	1.63	1.43
Square feet of total heating surface per I.H.P. (all machinery in operation) until last half hour of trial		2.44	
Square feet of total heating surface per I.H.P. (all machinery in operation) during last half hour of trial		2.34	
Square feet of grate surface in use until last half hour		1,408.	
Square feet of grate surface in use last half hour of trial		1,344.	
I.H.P. (all machinery in operation) per square foot of total grate surface until last half hour of trial		13 15	
I.H.P. (all machinery in operation) per square foot of total grate surface during last half hour of trial		13.77	
I.H.P. (all machinery in operation) per ton of propelling machinery, boilers and water		9.57	

THE COAL CONSUMPTION TRIAL.

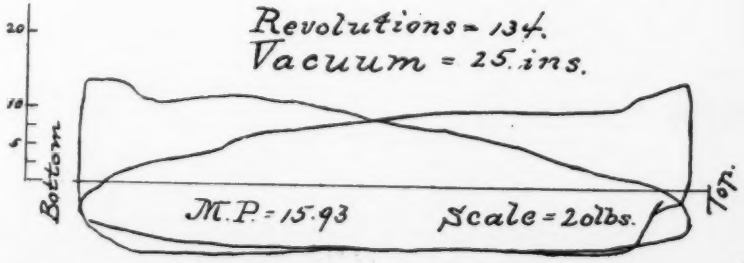
On November 19th, while on the return to Philadelphia, the ship was run for eight consecutive hours with the four after main boilers and two side engines, the center shafts being un-

U.S.S Columbia.
Starboard Engine.
2.10 P.M., Nov. 18, 1893.





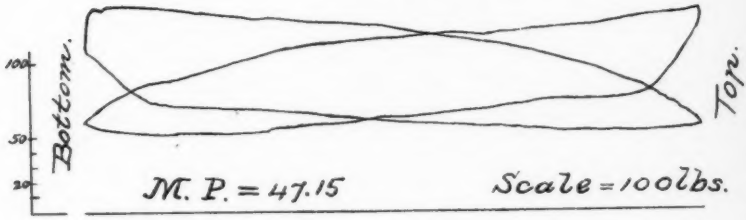
Revolutions = 134.
Vacuum = 25. ins.

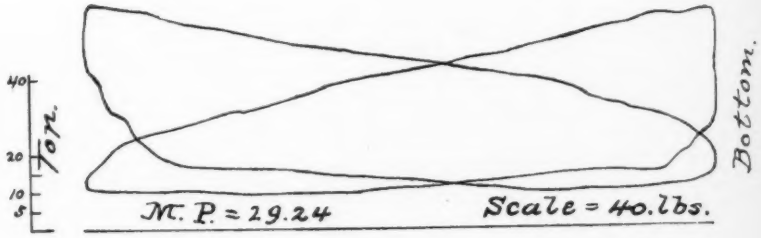


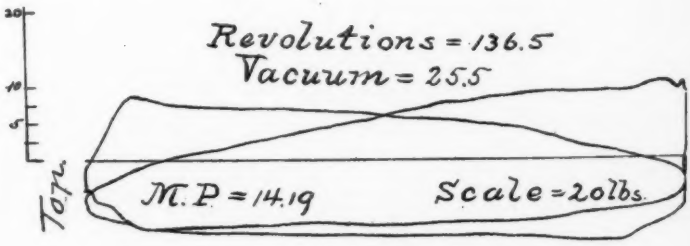
U.S.S. Columbia.

Port Engine.

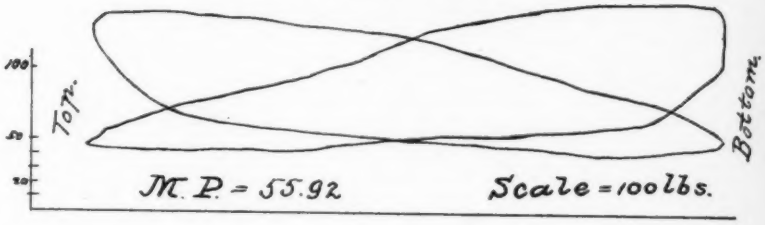
2.10 P.M., Nov. 18, 1893.

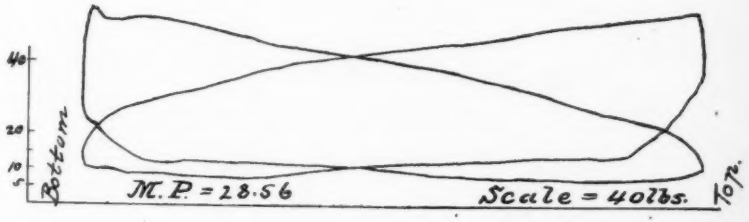




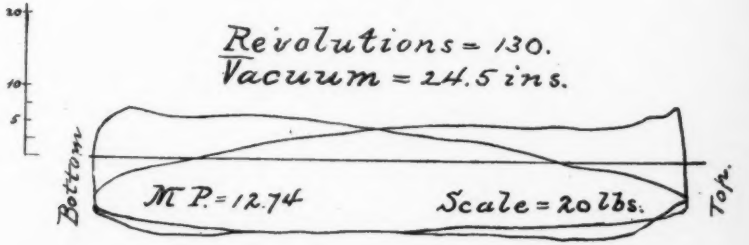


U.S.S. Columbia.
Center Engine.
2.10 P.M., Nov. 18, 1893.





Revolutions = 130.
Vacuum = 24.5 ins.

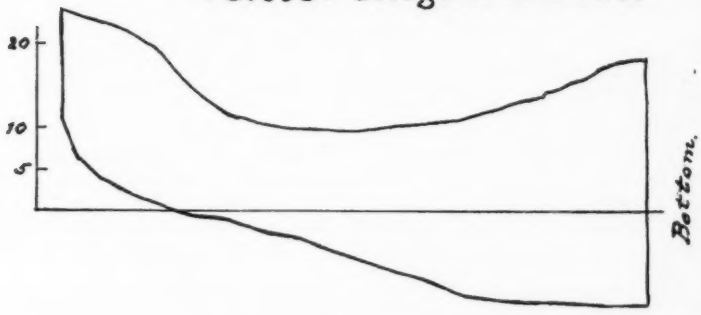


U.S.S. Columbia.

Air Pump Cards.

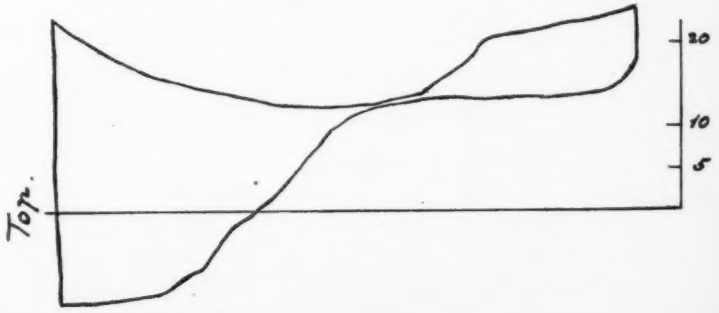
Starboard Cylinder

Center Engine Room.



2.10 P.M., Nov. 18, 1893.

Steam pressure	lbs.
Double strokes	12½
Vacuum	24.5 ins.
Scale	20 lbs.
IHP. (2 cylinders)	16.28



coupled, and the same air pressure and quality of coal as on the official trial.

The relative number of revolutions of the center propeller to the other is to be noted. The average speed may be accepted as correct, as the trial began and ended near well-established land marks, from which bearings were taken.

DATA OF THE COAL CONSUMPTION TRIAL.

Draught on trial, feet and inches	forward	19–7
	aft	22–3
	mean	20–11
Displacement at mean draught on trial, tons		6,666
Area of immersed midship section, square feet		1,031
Wetted surface (by calculation), square feet		26,320
Average speed, knots		18.87
Speed^3 × area of immersed midship section ÷ I H.P.		850.07
Speed^3 × displacement $^2/_3$ ÷ I.H.P.		290.57

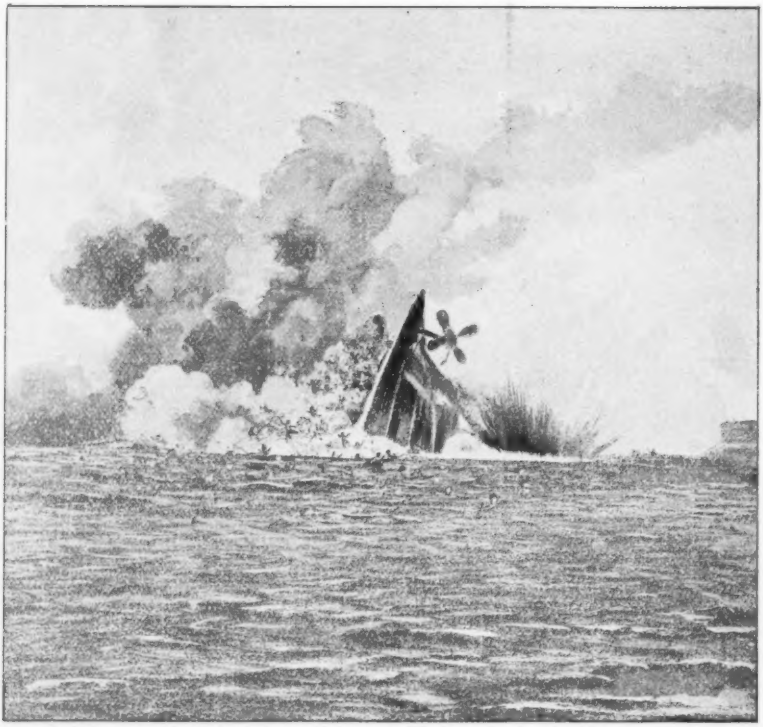
SYNOPSIS OF THE STEAM LOG.

		Port.	*Starboard.*
Slip of screws, per cent		23.37	21.26
Slip (mean of two screws) per cent		22.31	
Revolutions of center screw, shaft uncoupled		71.	
Revolutions of main engines, per minute		116.06	112.95
Revolutions, mean of two engines		114.5	
Piston speed, feet per minute		812 42	790.65
Steam pressure at boilers, per gauge, pounds		131.9	
Steam pressure at first receiver, absolute, pounds		48.8	50.2
Steam pressure at second receiver, absolute, pounds		18.8	20.1
Vacuum in condenser, in inches of mercury		25.7	24.5
Revolutions of main circulating pumps, per minute		132.7	105.
Double strokes of main air pumps, per minute		14.9	15.
Mean effective pressure in	H.P. cylinder	39.53	47.43
	I.P. cylinder	19.73	18.94
	L. P. cylinder	8.29	8.73
Mean effective pressure on L.P. piston, equivalent to aggregate M.E.P. on all pistons		24.47	26.21
I.H.P., H.P. cylinder		1,322.18	1,544.59
I.H.P., I.P. cylinder		1,316.56	1,229.72
I.H.P., L.P. cylinder		1,351.90	1,384.36
I.H.P., collective, of each main engine		3,990.64	4,158.67
I.H.P., collective, of both main engines		8,149.31	
Square feet of total heating surface in use		22,319.28	
Square feet of grate surface in use		672.	

QUALITY AND KIND OF COAL USED.

	Picked Pocahontas.
Net weight of fuel burned per hour, pounds	17,610.9
Pounds of fuel per I.H.P. per hour	2.16
Pounds of fuel per square foot of grate surface per hour	26.21
Pounds of fuel per square foot of heating surface per hour	0.789
I.H.P. per square foot of grate surface	12.12
Square feet of heating surface per I.H.P.	2.74

[We are indebted to the "Engineering Magazine" for the use of the half-tone of the *Columbia* forming the frontispiece of this paper.—ED.]



H.M.S. "VICTORIA,"

AS LAST SEEN OFF TRIPOLI, SYRIA, ON THE AFTERNOON OF JUNE, 22, 1893.

PHOTOGRAPHED BY STAFF SURGEON COLLOT, H.M.S. "COLLINGWOOD."

LOSS OF H.M.S. *VICTORIA*.

Report by the Assistant Controller and Director of Naval Construction [British] based upon Minutes of Proceedings of the Court Martial appointed to inquire into the cause of the loss of H.M.S. *Victoria*.

It has been thought desirable by their lordships that the minutes of evidence given before the court martial on the loss of the *Victoria* should be carefully gone through, in order that all important statements made by witnesses on matters relating to the collision between the *Camperdown* and *Victoria*, and the circumstances attending the subsequent sinking of the *Victoria*, should be summarized and classified. Having been directed to undertake this work, I now submit the following remarks:

The minutes of evidence being voluminous, and the evidence bearing on the matter above mentioned being scattered over the whole of the minutes, it appeared necessary to bring together in a tabular form and under various heads a summary of the statements made by various witnesses, giving the substance of each statement, as well as references to the original minutes of evidence. This has been done in the *Tabular Summary* annexed hereto, which is a digest of the evidence under the various headings herein contained. The reference to the original minutes will facilitate further investigation by any one desiring to form an independent opinion respecting the relative authority of different witnesses where their opinions differ.

As might be expected under the circumstances, witnesses are not in absolute agreement on every point. In many cases the impressions and estimates of individuals differ.

Such differences do not, however, affect the principal circumstances or the order of events from the time that the manœuvre began until the moment when the *Victoria* sank. On all essential matters there is practical agreement.

The investigations of the court martial were most searching,

and have put on record in a definite form the causes contributing to the loss of the *Victoria*.

Their lordships have desired also that I should prepare a report based upon the inclosed summary of evidence, in which the main facts established by the court martial should be set out briefly and in order. This has been done in the following pages. For the most part the statements made are supported by unquestioned evidence. Where differences of opinion occur in the evidence they are indicated. There are in most instances good grounds for reaching a decision, and an attempt is made to decide where the balance of evidence lies. In a few instances the evidence given before the court martial has been made the basis of certain calculations, the results of which are stated. Care has been taken to indicate clearly where the evidence is either criticised or supplemented.

From the evidence it is established that before the manœuvre began the ships were proceeding at a speed of 8.8 knots, the two lines being 1,200 yards apart.

When the signal to turn inwards 16 points was hauled down, the helm of the *Victoria* was put hard to starboard (35 degrees), which corresponded to a tactical diameter of about 600 yards. At the same moment the helm of the *Camperdown* was put at 28 degrees to port, which corresponded to a tactical diameter estimated at about 800 yards. Had the helm of the *Camperdown* been put hard to port, the tactical diameter would have been reduced about 20 per cent.

The two ships continued to turn under these conditions until they had each turned through about 8 points and were very nearly end-on to one another. Their distance apart at that instant was estimated at 2 to 2½ cables (400 to 500 yards). Both ships must then have acquired practically their full "swing" (or angular velocity) corresponding to the conditions of speed and helm angle above stated. Apart from change of helm or alteration in speed and direction of the engines, the ships would have continued to turn in practically circular arcs from 8 points onwards.

At or near the 8-points position it was recognized in both

ships that a collision was imminent, and steps were taken to avoid it if possible. The port engines of the *Victoria* and starboard engines of the *Camperdown* were ordered to be reversed practically at the same moment for the purpose of making the ships turn more quickly. These orders were given only about one minute before the collision took place. Assuming that the orders were executed with all possible dispatch, these engines could have been working astern only a very short time before the collision, so that the movements of the ships could have been but little affected thereby. The evidence bears out this conclusion.

In the *Victoria* the order to reverse the port engines was quickly followed by the order to reverse the starboard engines. The tendency, therefore, during the minute preceding the collision, was to somewhat check her headway. Captain Bourke considers she was moving at about 6 knots at the instant of collision. Staff Commander Hawkins Smith estimates the speed at not more than 5 knots.

In the *Camperdown*, according to Admiral Markham's and Captain Johnstone's evidence, it was intended to go *full-speed* astern with the starboard screw; but probably through some misunderstanding or error in working the telegraphs (not fault in the instruments), only *three-quarters' speed* astern was shown on the dial in the engine room; and the starboard engines were so worked up to the instant of collision. Almost simultaneously the order was received in the engine room to stop the port engines. The evidence of the engineer officer of the watch, and the chief engine-room artificer proves that the port engines were *stopped* for about one minute—that is, practically up to the instant of collision. They were then ordered to go three quarters' speed astern. Admiral Markham stated that he ordered full speed; but the seaman working the telegraph asserted that he received the order three-quarters' speed and acted on it. The engine-room staff, of course, only knew what the dial showed, and obeyed that order. While the misunderstanding is to be regretted, it cannot have sensibly influenced the result, since the interval of time was so short.

Witnesses differ in their estimates of the speed of *Camperdown* when she struck *Victoria*. Lieutenant Barr puts it at 4 to 5 knots, Captain Johnstone at 6 knots, Staff-Commander Hawkins Smith at 5 knots. Admiral Markham considered that the way of the ship had not been much checked.

This point admits of independent verification. The engine-room register of *Camperdown* shows that up to 8 points (90 degrees) in turning, the engines were running at 54 revolutions, corresponding to a speed on a straight course of $8\frac{3}{4}$ to 9 knots. In turning this speed would, of course, be reduced. According to records of turning trials of similar ships at about the speed in question, the speed from 8 to 12 points on an approximately circular path would be about 75 per cent. of the speed on a straight course before the helm was put over. The *Camperdown's* speed, therefore, at the moment when the starboard engine was reversed and the port engine stopped, must have been about $6\frac{3}{4}$ knots. In the brief interval—less than a minute—before the collision, this speed could have been but little lessened. Hence it appears that Captain Johnstone's estimate of 6 knots is fairly accurate and not in excess.

This is confirmed by the fact that, as the *Victoria* was using about 25 per cent. greater helm than the *Camperdown*, her speed on the circular path from 8 to 12 points must have been checked more from that on a straight course than was the case in the *Camperdown*. Moreover, both the *Victoria's* engines were reversed before the collision and only one engine in *Camperdown*. Consequently the *Victoria* must have been moving more slowly than *Camperdown*, and yet her speed as above stated was estimated at 5 to 6 knots.

There is practical agreement that both ships occupied about 1 minute in turning from 8 to 12 points, in which latter position they were when the collision took place. This estimate of time is confirmed by recorded observations on similar ships made during turning trials; and the fact that they were turning rapidly at the instant of collision had an important influence on the injuries received by both ships.

All the witnesses agree that the *Camperdown* struck the *Vic-*

toria nearly at right angles. The weight of evidence is in favor of the view that the keel line of *Camperdown* was about 10 degrees *abaft* the beam of the *Victoria*, the keel lines then being at an angle of about 80 degrees. This is confirmed by an examination of the paths actually traversed under similar circumstances by similar ships when turning from 8 to 12 points.

The blow was delivered on the starboard side of the *Victoria* about 65 feet abaft the stem-head, and just before important transverse bulkheads which extended from the keel to the upper deck. These bulkheads are lettered *E* and *F* where shown on Plates III to VI.

With the estimated speed of 6 knots the "energy" of the blow delivered by the *Camperdown* must have been about 17,000 to 18,000 foot-tons. This is about the muzzle energy of a 12-inch 45-ton B.L.R. gun, the estimated perforation of its projectile being about 22½ inches of wrought-iron armor.

Observers agree that this terrific blow delivered on the bow of the *Victoria*, at a time when she was rapidly turning, caused the fore end of that vessel to move about 60 or 70 feet to port. This bodily movement of the *Victoria* absorbed some of the energy of impact, and tended to lessen the shock and injury done to the structure. Even with this reduction the shock must have been very great. It caused a tremor throughout the whole length of the vessel, and the noise of the collision was heard on board other vessels at some distance from the *Victoria*.

The upper decks of the two ships were nearly at the same height above water. Before the *Camperdown* was "brought up" —which must have been done chiefly by the strong under-water protective deck of the *Victoria*—her stem and ram-bow penetrated some distance into the side of the *Victoria*.

Observers, for the most part, saw only the damage done to the upper deck of the *Victoria*. Several of the witnesses spoke of that deck having been broken and injured for a distance of 8 to 11 feet from the side. Accepting this estimate of the extent to which injury or disturbance was carried, it obviously does not follow that the upper portion of the stem of the *Camperdown* actually penetrated so far.

The best evidence on this point is to be found in the damage done to the bows of the *Camperdown*. Drawings and photographs have been received showing the nature and extent of that damage. Using this *data* in association with the evidence given respecting the movements of the ships while they were locked together, it is possible to decide with some certainty how far the *Camperdown's* stem entered the *Victoria*. On this basis the actual penetration (normal to the side) of the upper portion of the stem is shown to have been 5½ to 6 feet. (See Plate VI.)

When the ships collided, as explained above, they were both turning rapidly. Consequently after the bow of the *Camperdown* was engaged in the side of the *Victoria*, the sterns swung together to some extent. This fact was noted by several witnesses. Those most competent to form an opinion (particularly Lieutenant Barr of the *Camperdown*) state that the movement involved a swinging of the *Camperdown* relatively to the *Victoria* through an arc of about 20 degrees. It is stated further that the two ships were locked together for about a minute, before the *Camperdown* backed astern and cleared—which she did at an angle of about 30 degrees abaft the beam of the *Victoria*.

This swinging together of the two ships exaggerated the injuries done to both. For the *Camperdown* it probably meant the fracture of the stem forging; and it certainly involved very serious damage to the thin side plating on the port bow, which plating was broken through by contact with the side and decks of the *Victoria* abaft the breach made by the first impact. On the starboard bow of the *Camperdown*, where the swinging was practically a freeing movement, the damage done was relatively inconsiderable.

The damage to the port bow of *Camperdown* was chiefly caused by contact with the protective deck of the *Victoria*. The main part of the bow plating on both sides of the *Camperdown*, both above and below water, retained its general form. In swinging, therefore, the bow of *Camperdown* must have crushed in the adjacent plating and structure of the *Victoria* and produced a serious enlargement of the breach caused by the first blow.

Moreover it must have destroyed the watertight connection to the side plating of the important transverse bulkheads *E* and *F*, situated just abaft the place of collision. Those bulkheads consequently ceased to be watertight partitions for several feet from the starboard side of the ship.

A careful examination, based upon the known injuries to the plating on the *Camperdown's* port bow, and the angle abaft the *Victoria's* beam to which the *Camperdown* swung while she was locked, gives what must be a very close approximation to the extreme penetration into the side of *Victoria* effected by the stem of *Camperdown*. The result of this examination is shown on Plates III to VI, and indicates, as above stated, a penetration of about 5½ to 6 feet for the vertical portion of the stem. The extreme point or "spur" of the ram bow projects about 7 feet before the upright portion; and this spur pierced the thin plating below the protective deck, as it was designed to do. Notwithstanding the form of the athwartship section of the *Victoria* at the place of collision, the spur of the *Camperdown* was driven about 9 feet within the side plating, at a depth of about 12 feet below water. (See Plate VI.)

These results are of interest chiefly as a check upon the estimates of eye witnesses as to the extent to which the *Camperdown's* bow penetrated. It is important to notice, however, that even a considerably less penetration than that which has been shown to have occurred would have produced the same ultimate results by flooding the compartments to which water flowing through the breach could find access under the circumstances of the collision.

The ram bow of the *Camperdown* would have ripped open the thin bottom plating of the *Victoria* below the protective deck even if the vertical portion of her stem had not penetrated sensibly. Moreover, the *Victoria* was moving directly across the bows of the *Camperdown* at a speed of 5 to 6 knots. Apart from any sensible penetration of the *Victoria's* side, therefore, it was inevitable that, if this forward movement of *Victoria* relatively to the *Camperdown* had taken place, her bottom must have been torn open for some distance abaft the first breach,

during the time the vessels were in contact. This tearing action actually happened in the collision between the *Grosser Kurfürst* and *König Wilhelm*, when the former ship quickened her speed in the endeavor to clear the latter by crossing her bows.

As a matter of fact the *Camperdown's* bow was virtually *locked* in the protective deck of *Victoria* during the time the vessels were engaged together. The relative forward movement of *Victoria* across the *Camperdown's* bow was thus practically destroyed, and consequently the tearing action of the spur on the bottom plating was lessened; although the swinging movement above described necessarily involved an enlargement of the breach.

It is possible, following the method above described, to closely approximate to the area and form of the breach made in the side of the *Victoria* by the collision and subsequent swinging together of the ships. The result is shown on the diagram.

The breach must have extended vertically from the upper deck to a point about 28 feet below that deck, and 18 feet below the water-line at which *Victoria* floated before collision.

The width of the breach varied. At the upper deck it was about 12 feet; at the original water-line about 11 feet; then it gradually diminished in general breadth towards the lower termination. The area of the breach below the original water line must have been 100 to 110 square feet.

The bow of the *Camperdown* filled this breach to a large extent during the minute the ships were locked together. When the *Camperdown* went astern and cleared, the full area of the breach was left open to the entry of water. The initial rate of inflow of water through an unobstructed aperture of this size would be over 3,000 tons per minute. The actual rate of inflow was governed by many circumstances. Compartments which were directly breached by the blow and put in free communication with the sea must have filled very quickly. These compartments, in the aggregate, required only about 500 tons to fill them, so that they were probably flooded to a serious extent before the *Camperdown* cleared.

The whole arrangements of the water-tight subdivisions forward are indicated on Pates III to VI. It will be seen that the spaces below the main deck were minutely subdivided by transverse bulkheads, horizontal decks and platforms, and a few longitudinal bulkheads. The governing idea, as in all war ships, was to turn each compartment necessary for stowage into a separate water-tight enclosure when doors, scuttles, &c., were closed and secured. The evidence establishes the fact that a number of these doors, &c., were open at the instant of collision, and could not be subsequently closed. Further, the shock of collision no doubt destroyed the absolute water tightness of some of the partitions adjacent to the place where the blow was struck, so allowing water to pass through interstices.

Water entering through the breach could not pass away into compartments adjacent to those first put directly into communication with the sea at anything approaching the rate of inflow appropriate to the unobstructed motion due to the area and depth of the breach below the water surface. It had to find its way through doors, scuttles, &c., at a rate determined by the area and positions of these openings. Even when thus checked, the evidence clearly shows that a very large weight of water found its way into the interior, and passed for a considerable distance fore and aft in a very short time. A very great depression of the bow was observed within three or four minutes of the collision.

It is proved by the evidence that the water-tight doors, hatches, &c., were in good order and perfectly efficient. The ship had been recently recommissioned at Malta, and had passed through the dockyard hands, all defects having been made good. The Chief Constructor of Malta Dockyard certified to this fact, and his evidence is confirmed by that of the officers of the *Victoria*. Moreover, the men who closed, or attempted to close, the doors, &c., with one single exception, made no statement suggestive of any fault in these fittings. The exception applies to a sliding door in bulkhead H, below the protective deck and just before the turret. This door could not be closed completely. No sufficient reason is given for the stoppage. Captain Bourke suggests

that the shock of the collision may have disturbed the fittings. This view is not concurred in. The bulkhead in question is of exceptional strength, being one of the principal supports of the athwartship armor at the end of the belt. It is situated 35 feet from the place where the blow was struck, and many doors much nearer to that place were shown by the evidence to be uninjured. Most probably there was some temporary obstruction to the closing, and the evidence of Rufus Ruff shows that he had no time to look carefully into the matter, as water was rushing into the compartment from forward.

It should be noted that the failure to close this door was not a matter of great importance under the circumstances, because the compartment abaft, to which (according to the evidence) water could find access, only contained 75 tons, and the effect of that small additional weight of water was trivial compared with that of over 1,000 tons in other flooded compartments.

The true cause of failure to close the doors, hatches, &c., in the forward part of the ship is to be found in the very short time before the collision that orders were given to make the attempt. Captain Bourke states that under ordinary conditions of drill, with a trained crew, *three minutes* were required to close the doors, &c. It is also proved that the order to close doors was given about *one minute* only before the collision. The men were in their messes or on deck for the most part when this order was given. Using all possible exertions they could not reach the compartments forward, and especially those below the protective deck, in time to do much, if anything, before the collision had happened, and large quantities of water were entering. In the evidence this is conclusively proved by incidental statements made by the men. Abaft the turret the case was different; as water took some time to find its way into those compartments, the men could work without disturbance or danger, and the doors, &c., were closed and secured.

In the course of the inquiry many allusions were made to the possibility of partitions originally water tight having ceased to be so in consequence of the great shock sustained by the structure. No doubt damage of the kind occurred in the immediate

neighborhood of the place where the blow was struck, and it is not possible to determine exactly the limits wherein such damage may have been sustained.

There is indirect evidence that the extent of serious disturbance by shock was not so great as some persons have supposed. For example, the anchor on the starboard side, only about 20 feet before the breach, remained in place after the collision. Again, two witnesses testified that after the collision they were able to close and secure a door in the divisional bulkhead on the mess deck, only 10 or 12 feet from the place where the blow was struck, and about 10 feet from the ship's side. Experience in other cases of collision confirms the view that serious damage is likely to have been localized in close neighborhood to the place where the blow was struck. This is quite consistent, moreover, with the tremor consequent on collision being felt at a considerable distance from that place.

The point has but little real importance, however, because, as above stated, it is established by evidence that doors, &c., were not closed both in partitions which it is reasonable to suppose might have been affected by the shock, and in others which were further off the seat of injury, and consequently not likely to be disturbed.

From the evidence it is possible to ascertain, in considerable detail, facts concerning the behavior of the *Victoria* from the instant of collision up to the time she foundered. The impressions of various witnesses have been grouped in the Tabular Summary of Evidence annexed hereto. It will be seen that, while there is agreement on important points amongst those who were well placed for observing the movements of the ship, other spectators less favorably placed give somewhat different accounts and estimates.

The most valuable evidence on these points is that of Staff Commander Hawkins Smith and Flag Lieutenant Lord Gillford, of the *Victoria;* Captain Moore, of the *Dreadnought*, and Captain Noel, of the *Nile*. These officers are in substantial agreement, and their evidence is supported by that of other witnesses in

most particulars. From these sources the following account has been framed:

The *Victoria* and *Camperdown* remained locked together about one minute. During this short time the *Victoria* is thought to have heeled slightly to the starboard side, and settled a little by the bow.

When the *Camperdown* had gone astern and cleared, the *Victoria* continued to settle by the bow and to increase her heel to starboard. For nine or ten minutes these movements continued to proceed gradually and steadily. Then came a "lurch" to starboard, which commenced suddenly. The ship fell over on her side, and, turning bottom up, finally sank by the head at an angle of 20 or 30 degrees to the vertical. At the instant the lurch began the *Victoria* was steaming slowly ahead with both screws, her helm being hard-a-starboard. The intention was to make for the land.

For convenience it will be desirable to consider separately the two movements which proceeded simultaneously, viz: depression of the bow and heel to the wounded (starboard) side.

It appears that about 4 minutes after the collision the bow had dipped so much that water was coming through the hawse pipes on to the upper deck—that is to say, the bow had sunk about 10 feet in 4 minutes. This change of trim continued, and about 2 minutes later the water had risen so much on the forecastle that men who had been working there were called away. Immediately before the lurch took place the water was washing into the open turret ports, situated nearly at the middle line 100 feet from the bow, and at a height of 14 feet above the original water line. Captain Moore states that the water was then half-way up the turret wall; and Captain Noel saw the water 2 to 3 feet deep against the sides of the turret. On investigation it is found that at this moment (accepting Captain Moore's careful observations) the upper deck right forward was 13 feet under water, having been depressed about 23 feet below its original position. The forward part of the upper deck was then almost entirely under water, from the bow to the bulkheads forming the forward termination of the upper-deck battery. In other words, nearly half

the length of the ship was submerged. The after portion of the ship was lifted considerably above its normal position, and the upper blades of the port screw were showing above water to a large extent. The normal position of the tips of the blades was 11 feet below water. This emergence of the screw was partly due to the heel, but chiefly to change of trim.

Simultaneously with this extraordinary change of trim by the bow, the *Victoria* was heeling to starboard. All the witnesses on board that ship agree that the motion was gradual and steady until the lurch took place. Their conclusion is supported by witnesses from other ships, and by the fact that 9 or 10 minutes were occupied in reaching a heel of 18 or 20° from the vertical. There is practical agreement that this was about the heel to starboard at the moment when the lurch took place.

Captain Moore, who was taking note of the *Victoria* at that time, confirms this estimate, and adds some most important information. He saw the water half-way up the turret wall; and consequently it must have been flowing through the open ports into the turret, from which it could pass into the redoubt, surrounding the turret base, and thence could find access to certain spaces below.

Further, he noted that the armor door in the oblique bulkhead at the further end of the upper-deck battery was partly under water. It has been given in evidence that this door was never closed. Consequently water was at the same time passing into the battery and accumulating on the starboard side. Captain Moore remarked also that the two foremost 6-inch gun ports on the starboard broadside were then *just awash*. These ports, according to the evidence, were not closed, and therefore when they became "awash" large quantities of water could enter rapidly. In these circumstances it is obvious that a sudden increase of heel was inevitable; and the ship had sustained such a loss of stability from the submergence of her bow and the rise of her stern that she could not recover herself, and eventually capsized.

Captain Noel describes the motion of the *Victoria* at this time in some detail. He says she fell over to starboard slowly at first,

but afterwards with increasing rapidity. He adds the important fact that as this movement took place boats and other weights fell to leeward with a terrible crash. This "fetching-away" of weights no doubt contributed to hasten the capsizing when the motion had begun. It is practically certain, also, that large quantities of water which entered the upper-deck battery, through the open ports and armor door, must have passed below into the deck and hold spaces through open hatchways, doors, &c., thus flooding the ship and further accelerating her foundering.

The attempt made to steam toward the land with the helm hard-a-starboard tended to increase somewhat both the depression of the bow and the heel to starboard. It is true that only a low speed was reached, but with the forcastle buried deep under water any headway tended to further "tip" and heel the vessel, and to accelerate the inflow of water through the turret ports and battery door. The transverse stability had been so seriously diminished by the submergence of the bow that inclining forces of small absolute amount, which would have been of no importance in the ordinary condition of the ship, produced an appreciable effect.

The hydraulic steering gear in the *Victoria* ceased to act very soon after the collision. Captain Bourke attributes the circumstance directly to the inflow of water consequent on the collision. His opinion is concurred in. It is important to note that this steering gear had given no trouble previously, and that alternative hand-steering gear, placed far abaft the compartments flooded, was still available for controlling the ship. This hand gear could be brought into operation very quickly when required, and was of ample power for moderate speeds. That it was not used was undoubtedly due to the short time the ship remained afloat.

Passing from the behavior of the *Victoria* during the interval before she sank, to the consideration of the causes which produced the great change of trim and the heel to starboard observed, it is necessary to examine closely into the facts placed before the court martial respecting the compartments which were flooded. The evidence on these points is exhaustive, and has been classified in Section VII of the Tabular Summary annexed.

Up to the time when the ships had turned 8 points—or about one minute before the collision—no orders were given to close the water-tight doors, etc., then open. It was "make and mend" afternoon, and the men were in their messes. After the orders were given every possible endeavor was made to close doors and scuttles; but the time available was very short and the inrush of water was rapid. The court martial examined individually the officers and men who closed or attempted to close doors and scuttles. It is clear from the evidence that in some cases doors, etc., which were attempted to be closed were not properly secured, or really made water-tight, the men having no time or being driven away by the inrush of water.

An important example of this occurs in the evidence relating to the door in the bulkhead E_2 at the forward end of the submerged torpedo room (see plate V). Petty-officer Jacobs stated that he proceeded from the spar deck to this compartment and closed the door in question. It will be seen that the compartment before the bulkhead E_2 was breached, as the *Camperdown* swung while locked in *Victoria;* consequently it must have been in free communication with the sea. Jacobs confirmed this and admitted that he might not have completely secured the door. Another witness (Rufus Ruff) proved that, whatever Jacobs may have attempted, water in considerable quantities was passing through the bulkhead at or near the place where the door was fitted, which Jacobs thought he had closed. This door was situated about 30 feet from the breach made by the *Camperdown's* bow, and the nearest part of the bulkhead on the starboard side was about 10 feet abaft the breach (plate VI). It appears highly probable, therefore, that neither the bulkhead nor the door could have been seriously damaged, so as to admit the quantities of water seen by Ruff, and that Jacobs failed to close the door, although he made the attempt.

This has been described both as a typical case of what must have happened in many instances under the circumstances, and because it is the only important point in which reason is seen to differ from the statement put in by Captain Bourke as to doors which were closed. Its importance arises from the fact

that the flooding of the submerged torpedo room involved the entry of fully 260 tons of water into that space, and its passage aft into spaces below the turret. Having regard to the evidence of Ruff, it is certain that the submerged torpedo room was flooded.

On the basis of the facts set out in detail in Section VII of the Tabular Summary of Evidence, diagrams have been prepared which graphically illustrate the extent to which the *Victoria* was flooded. The evidence of Captain Bourke has been generally followed, but on the unquestioned evidence above mentioned it has been accepted that the submerged topedo room was flooded. Further, the water-tightness of the provision room and of the compartment in hold between stations 12 and 22, port side (Plate V), has been taken as *not* destroyed by the shock of the collision.

These diagrams show—

(*a*) The compartments which would have been flooded as a necessary consequence of the collision, if all doors, &c., in bulkheads and platforms had been closed prior to the collision.

(*b*) The compartments subsequently flooded through doors, hatchways, &c., which remained open after the collision.

(*c*) The compartments respecting which the evidence is doubtful, and into some of which water may have found its way because doors and hatches were not closed.

On these diagrams are also indicated the probable positions of the bow of the *Camperdown* as she struck and after she swung towards the *Victoria* before clearing.

In deciding on the compartments under group (*a*) care has been taken to include all spaces which could reasonably be supposed to have been injured by the collision in such a way as to permit access of water to them. It has been explained above that the extent to which the shock may have carried injuries is not absolutely determinable, but that there are good evidences that the principal effects were comparatively local.

The other groups are based strictly on the evidence, with the correction as to the bulkhead E_2 above described.

The facts represented graphically in Plates III to VI have been grouped in the following tables. The flooded compartments

TABLE I.—COMPARTMENTS SHOWN BY THE EVIDENCE TO HAVE BEEN THROWN OPEN TO THE SEA EITHER BY DIRECT DAMAGE OR THROUGH OPEN DOORS, HATCHES, &c.

Name of compartment.	Loss of buoyancy, in tons.	Distance in feet from—	
		Middle of length of ship.	Middle line of ship—starboard side.
Above protective deck—			
Small compartment leading to capstan flat	8½	132	—
Fresh-water tank room	25	122	—
*Cable lockers	34	109	—
*No. 1 coal bunker, 18 to 23, starboard side	8	108	18
*Coal bunkers Nos. 3 and 5	33	87	14
Total above protective deck	108½		
Platforms to protective deck—			
Compartment fore end of capstan room	18	130	—
*Capstan engine room	80	116	—
*Carpenter's store, 14 to 22	50	114	13
*Torpedo flat, 22 to 27	200	96	2 port side.
Submerged torpedo room	260	78	—
Spaces between 35, the ring bulkhead, and 43	75	62	—
Hold below platforms—			
*Water-tight compartment starboard side, 12 to 22	108	117	6
*Water tight compartment below, from 12 to 22	20	117	4
*Water-tight compartment, 22 to 31, starboard side	50	88	18½
*Water-tight compartment below provision room, &c., 22 to 31	60	88	—
*Torpedo magazine, or gun cotton magazine	33½	98	8
No. 7 coal bunker and shoot	47	44	25
Total below protective deck	1,001½	—	—
Grand total	1,110	—	—

NOTES.—1. The compartments marked with an asterisk are those (included in group (*a*) above), which it is considered must have been flooded in consequence of the collision, even had doors, hatches, &c., been closed prior thereto.

2. For compartments above the protective deck the loss of buoyancy (108½ tons) is estimated up to the water line at which the *Victoria* floated before the collision. This loss will be seen to be about 10 per cent. of the total loss. Had no loss taken place below the protective deck, the flooding of compartments named above that deck would have produced a change of trim of only 3 feet and a heel of less than 3 degrees. When the compartments below the protective deck were also flooded the change of trim became 29 feet, and the heel to starboard 18 to 20 degrees.

TABLE II.—COMPARTMENTS SHOWN BY THE EVIDENCE TO HAVE BEEN PROBABLY OR POSSIBLY FILLED THROUGH DOORS, HATCHES, &c.

Name of compartment.	Loss of buoyancy, in tons.	Distance in feet from—	
		Middle of length of ship.	Middle line of ship—starboard side.
Above protective or lower deck—			
Air compressing room, port side	22	39	16 port side.
Sail room, chest room, torpedo room, with turret support, 35 to 53	300	54	1½
Platforms to protective or lower deck—			
Compartment between bulkheads, 43 and 53, and turret support. Space for empty powder cases	200	47	—
Hold below platforms—			
Water-tight compartment, port side, 12 to 22	180	117	6 port side.
Port ejector tank	35	70	19 " "
Total	665 tons.	—	—

NOTE.—All the compartments mentioned in Table II, except those below platforms, are within the limits of the armor belt.

TABLE III.—COMPARTMENTS ULTIMATELY FILLED THROUGH RIDING BITTS BY THE DEPRESSION OF THE BOW.

Above protective deck—			
Boatswain's and carpenter's stores, 7 to 14	100	138	—

have been enumerated and classified, and for each of them the "loss of buoyancy" consequent on flooding has been calculated in the constructive department of the Admiralty. These calculations are of the simplest character, dealing only with the *unoccupied spaces* in flooded compartments, and the positions of the centers of gravity of those spaces.

In the Minutes of Evidence (pages 132 to 133) it will be seen that the court martial had a somewhat similar statement presented to it by Mr. Newnham, chief constructor at Malta. That officer, however, had not the full evidence before him at the time,

and made certain assumptions as to the compartments flooded which are not borne out by the evidence. For example, he assumed that on the platforms (Plate V), the water did not pass abaft the bulkhead E_2, whereas it was proved to have reached I bulkhead, about 36 feet further aft than E_2. Under these circumstances Mr. Newnham's calculations do not represent the actual conditions, and need not further be considered. His estimates for the capacities of compartments are, on the whole, in fair agreement with those given in the preceding tables.

Taking the facts established by the evidence, and recorded in Table I, an enquiry has been made into the effect which flooding the compartments therein enumerated should have had upon the trim and transverse inclination of the *Victoria*. This enquiry has necessitated the performance of certain calculations in the constructive department of the *Admiralty*, those calculations being based upon well-known principles which are universally applied in estimates of the buoyancy and stability of ships. The following is a summary of results:

1. The flooded compartments (19 in number) had a capacity which involved a total "loss of buoyancy" (up to the original water line) of 1,110 tons; of this amount less than 110 tons were in compartments above the protective deck, and about 1,000 tons in the spaces below that deck.

2. This loss of buoyancy in compartments so far forward produced a "moment to change trim" of about 140,000 foot-tons. Of this total moment the 110 tons above the protective deck account for only 15,000 foot tons—the balance, nine-tenths of the whole, being due to the water below that deck. The moment due to the 110 tons above the protective deck corresponds to a change of trim of 3 feet only. The additional moment due to the 1,000 tons below the protective deck brings up the change of trim to the enormous amount of 29 feet. Allowing, as is done only for compartments enumerated in Table I, the calculation shows the depression of the bow to be about 21 feet, and rise of stern 8 feet, as compared with their positions before the collision took place. Such a change of trim, however, necessarily flooded also the compartments named in Table

III. Consequently, the final depression of the bow, by calculation, fully equals that which was observed by several witnesses as having been reached before the lurch began, and which is estimated from their evidence at 23 feet.

3. As the bow sank, water entered the upper part of the vessel through the breach and filled all the space between the upper and main decks back to the oblique water tight bulkheads shown on Plate V as situated just abaft the turret.

Certain small store rooms (Plate IV) were also filled from above as the bow sank, but this circumstance was relatively unimportant.

4. Neglecting water which may have entered through the turret ports, when the *Victoria* had reached the position occupied before the lurch, there must have been about 2,200 tons of water in the interior of the ship, before the fore boiler room and below the upper deck (Plates III to VI).

5. The case was aggravated by the entry of water into the turret, redoubt, and spaces below.

6. As explained above, the sudden entry of water into the 6-inch gun battery above the upper deck through the open ports and door, caused the final lurch which led to the capsizing and foundering of the vessel.

7. Had the ports in battery and turret, and the armor door been closed and water excluded from both battery and turret, the *Victoria* would not have capsized, and would have remained afloat for a much longer time even if eventually she had foundered.

It is not possible to state absolutely that the *Victoria*, with turret and battery closed, could have been kept afloat permanently under the actual circumstances of the collision. There are so many compartments (see Table II) into which water may have found its way eventually, through doors or hatches respecting which there is no direct evidence whether they were closed or not. But this would have involved still further change of trim by the head, and her capsizing would have been improbable even if she had eventually foundered.

Allusion has been made above (page 50) to the great reduction

in stability necessarily produced by such an extreme submergence of the bow and accompanying rise of the stern as were observed in the *Victoria* before the lurch began. This fact is well known to naval architects, and can be readily understood apart from exact calculations.

The power of a ship to resist inclination from any position in which she floats at rest depends greatly upon the moment of inertia of her buoyant water-line section (or plane of flotation). Any causes which reduce this moment of inertia lessen the stability. To illustrate the remarkable change, which the submergence of the bow and consequent entry of water into the *Victoria* produced upon the form of the buoyant water-line section, two diagrams have been prepared (Plate II).

The first diagram shows the form of the water-line section of the ship when intact, as she floated before the collision, contrasted with the corresponding water-line section which she must have had before the water entered the turret through the gun ports and the upper deck battery through the armor door and 6-inch gun ports. In the latter condition the power to resist transverse inclination still remains, but is only about *one-sixth* of the corresponding power when the ship was intact and upright. Before the collision the *Victoria* had a metacentric height of 5 feet. After the collision, when her bow had sunk deeply and she had heeled considerably, the corresponding metacentric height was about *eight-tenths* of a foot.

The second diagram in Plate II similarly contrasts the water-line section when the ship was intact and upright with her water-line section when the water had entered the battery and turret, as observed at the moment before the lurch began. The consequent reduction in buoyant water-line area caused a still further fall in the metacenter, and instead of being five feet above the center of gravity it was 1.8 feet below that point. In other words, the ship had become unstable and lost the power to right herself.

Submergence of the bow and entry of water also seriously diminished the power of the ship to resist changes of trim. In the damaged condition this was only about *one-third* as great as

in the intact condition, even supposing water to be excluded from the turret and the battery. Hence appears more clearly the force of the remarks made above as to the possible influence of even slow motion ahead in producing greater depression of the bow.

The foregoing considerations have an important bearing on the heeling which accompanied change of trim in the *Victoria*. No doubt the primary cause of the heel to starboard must be found in the circumstance that the first rush of water filled very rapidly certain compartments on the wounded side. Subsequently the water found its way into other compartments through open doors or scuttles, or damaged bulkheads, but this, as above remarked, was comparatively a slow process, as is proved by the movement of the ship, both in heeling and changing trim.

Although the water sought to find its level, there must always have been a preponderance on the wounded side, and possibly this increased gradually.

In the forward part of the *Victoria* there *is no continuous central longitudinal bulkhead*. That feature does not appear in the vessel except in the stokeholds and engine room, which were far abaft the place of collision. It is established by the evidence that water had not entered even the foremost stokehold up to the moment immediately preceding the commencement of the lurch.

There were a few longitudinal partitions in the forepart of the ship, built primarily for the enclosure of compartments needed for stowage of stores, provisions, &c., and then made water tight. (See Plates IV to VI.) Many of these partitions were inoperative because of damage or open doors. The few which remained intact did not produce such an eccentric distribution of buoyancy as would have been of any importance had it not happened that the submergence of the bow so seriously diminished the transverse stability. This statement has been made because, by some persons, the capsizing of the ship has been supposed to have resulted from the presence of central longitudinal subdivisions.

One of the chief causes of inclination to starboard is to be found in the fact that, owing to open doors, water was able to find its way from bunkers above the protective deck down through

the coal shoot, and so to fill No. 7 bunker (see Plate V) just before the forward starboard stokehold.

In Table I are stated in detail the capacities and transverse positions of the centers of gravity of all the eccentric compartments which were flooded. In the intact condition of the ship the heel corresponding to the flooding of these compartments would have been only about five degrees.

As the bow dipped and the transverse stability consequently became reduced the effect of this inclining moment became greater.

It appears on investigation that in the damaged condition and at the extreme position which the *Victoria* occupied before the lurch began, the flooding of the compartments enumerated and the accumulation of water on the starboard side, account for the observed angle of heel, 18 to 20 degrees.

That lurch commenced, as was explained above, when water rapidly entered the battery in large quantities through the armor door and the broadside gun ports. The effect of the inrush of water was magnified by the great reduction in transverse stability which resulted from the enormous change of trim. Had the door and ports been closed and the entry of water into the upper-deck battery thus prevented, then calculation proves that, sorely wounded as she was, the *Victoria would not have capsized.* Only a short time before the lurch took place, orders were given to close the gun ports, but these orders could not be executed. No attempt seems to have been made to close the armor door at the fore end of the battery. The door and ports were not included in the "Collision Stations," and therefore would not be closed as a part of the drill.

If the *Victoria* had been at sea in bad weather these gun ports and the armor doors would have been closed and secured so as to maintain the integrity and water-tightness of the high after part of the ship containing the 6-inch guns. In fact the safety of the ship in heavy weather when rolling through large angles would obviously have required precautions to be taken to keep openings into the 6-inch battery closed and to keep water out.

Under the actual circumstances of the collision, with the ships

moving in smooth water, it was natural that both ports and doors should have been open. But when, by the entry of large quantities of water forward, the bow had been so greatly depressed and the transverse stability so largely reduced, the safety of the ship became dependent upon the exclusion of water from the turret and battery to an even greater extent than would have held good when rolling heavily at sea but with full transverse stability maintained.

Consideration has been given also to the probable effect of the collision *had all doors, hatches, &c., been closed prior thereto.* In Table I, as explained above, an attempt has been made to distinguish those compartments which would necessarily have been thrown open to the sea by the collision. Differences of opinion may arise as to the extent to which absolute water-tightness in partitions may have been affected by the shock, but there is obviously an essential difference between serious damage admitting the passage of large quantities of water in a short time, and an interference with absolute water-tightness in bulkheads, decks, &c., which would permit only small quantities of water to pass at a slow rate. Taking the compartments marked by an asterisk in Table I as a fair measure of the probable extent of damage, then calculations show that the effect of the collision would have been as follows:

(1) The flooded compartments would have been 12 in number, and would have involved a loss of buoyancy of 680 tons; of this loss 600 tons would have been below the protective deck.

(2) The moment producing change of trim corresponding to this loss of buoyancy would have been 90,000 foot-tons.

The change of trim resulting would have been 13½ feet, or less than half that observed before the lurch began. The upper deck at the stemhead would have remained just above water.

(3) The heel to starboard would have been about nine degrees.

(4) The ship would have retained ample transverse stability, the metacentric height being 2½ feet.

(5) The forward 6-inch gun ports would have remained 4½ feet above water.

Under these circumstances the *Victoria* should have been under control and navigable.

The diagrams in Plate I have been prepared for the purpose of illustrating the results of calculations made at the Admiralty.

Fig. 1 shows the *Victoria* intact and upright.

Fig. 2 shows her in the position it is estimated she would have occupied after the collision had the water-tight doors and hatches been closed prior thereto.

Fig. 3 shows her in the position it is estimated she would have reached had all the compartments enumerated in Tables I and III been flooded, but on the supposition that *water had been kept out of the battery and turret.* This corresponds to the conditions illustrated by the upper diagram in Plate II. The estimated change of trim is close to that observed by Captain Moore, and the estimated heel is rather less than that observed. This should be so as the water was not actually kept out of the battery or turret and, accumulating on the starboard side, must have increased the heel.

Had the battery and turret been kept free of water then, even if the *Victoria* had been inclined to 30° from the upright she would have had a *righting* moment of about 6,000 foot-tons.

On the contrary, when (as actually happened) water could find access to the battery and turret, the stability was destroyed; and at 30° of inclination there would have been an *upsetting* moment of 4,000 foot-tons.

The failure to close the water-tight doors in the forward part of the *Victoria*, and the similar failure in the *Camperdown*, has caused suggestions to be made that automatic or "self-closing" doors should be adopted instead of existing arrangements.

This suggestion is a revival of one made long ago, then carefully considered and put aside after certain experimental doors had been tried.

Automatic arrangements are applied in valves to ventilating trunks and other small openings in bulkheads and platforms. Even in such cases the feeling of the Naval Service has led to the automatic fittings being supplemented by the means of closing the valves when desired. In doors and scuttles the risks of

the automatic appliances failing to act, or of solid materials being carried into openings by a rush of water, and preventing doors from closing properly, would be much greater.

These considerations have led to the retention of existing fittings, the design of which provides that, when properly closed and secured, doors and hatchway covers shall be as strong as the neighboring partitions, and water-tight under considerable pressure.

There is no mechanical difficulty in making automatic appliances. It is a question of what plan secures the maximum of safety under the working conditions of the Royal Navy.

With large numbers of disciplined men familiar with the fittings, and constantly drilled in their use, it is possible to close and properly secure all the doors, &c., in a battleship in three to four minutes, or possibly a less time for ships after long periods in commission.

In the *Victoria*, as above stated, no orders were given to close doors until one minute before collision. It is established by the evidence that the doors, &c., were in good order. The failure to close doors, therefore, was due entirely to the insufficiency of the time available, especially in compartments breached by the collision.

Under these circumstances no new argument in favor of the use of automatic doors seems to arise out of the loss of the *Victoria*.

It has been asserted that if a strong armor belt had existed at the place where the blow was struck, the damage to *Victoria* might have been greatly reduced and the ship kept afloat. From the foregoing remarks it is clear, however, that even if the belt had been so strong as to absolutely resist penetration, the thin bottom plating below it must have been very seriously damaged by the spur of the *Camperdown*, and the thin side above it must have been so injured as to cease to be water tight. All the most important compartments which were flooded in *Victoria*, therefore, must have been thrown open to the sea under the conditions of the collision, even if there had been such a belt. The breach in the side might have been different in form and possibly

H. M. S. "VICTORIA".

Scale 0 10 20 30 40 50 60 70

FIGURE (1). *Ship*

FIGURE (2). *Calcul*
inerti

FIGURE (3). *Calcul*
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doors
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of shi

FIGURE (1).

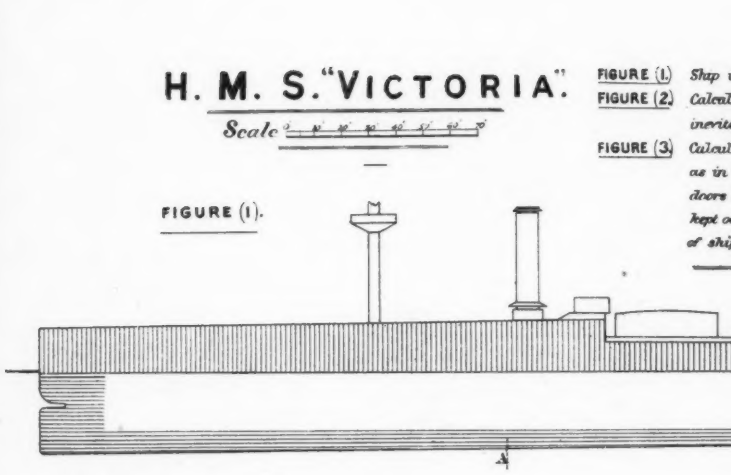


FIGURE (2).

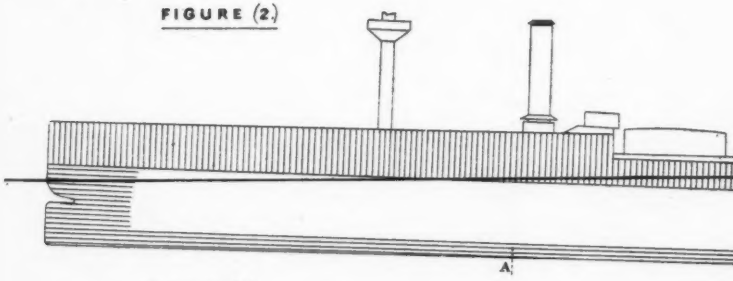
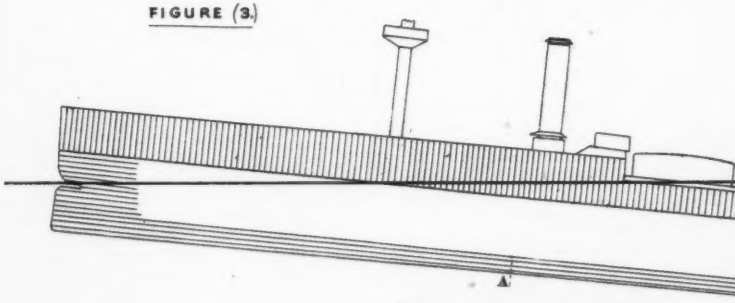


FIGURE (3).



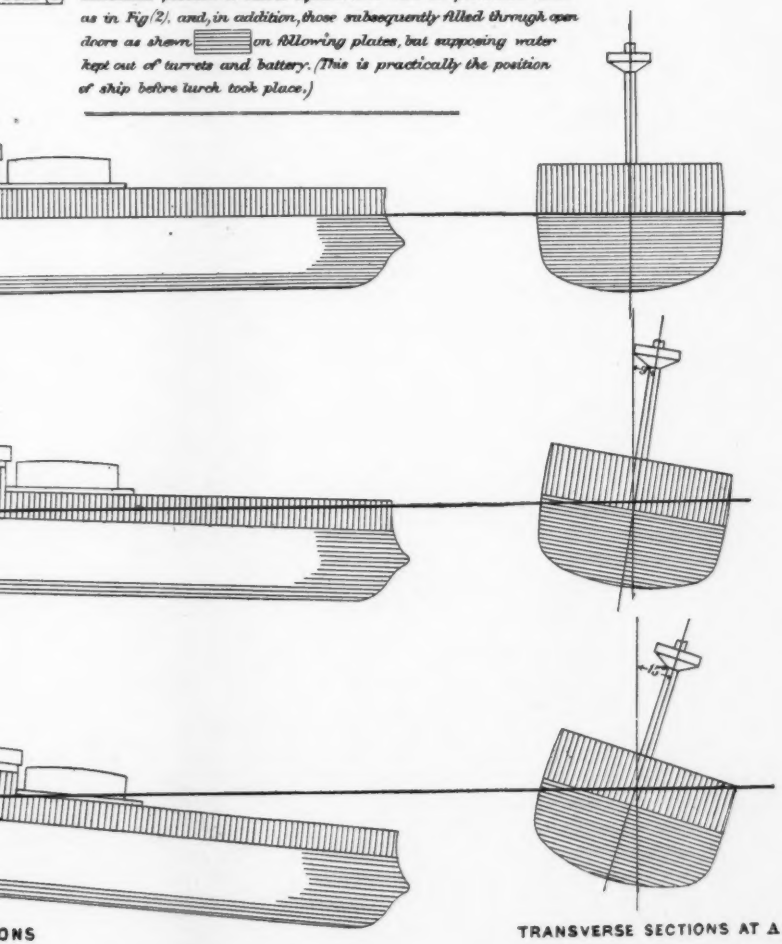
LONGITUDINAL SECTIONS

GURE (1.) *Ship intact before collision.*

GURE (2.) *Calculated position of stable equilibrium of ship with compartments inevitably flooded, as shewn* ▭ *on following plates.*

GURE (3.) *Calculated position of stable equilibrium with compartments filled as in Fig (2), and, in addition, those subsequently filled through open doors as shewn* ▭ *on following plates, but supposing water kept out of turrets and battery. (This is practically the position of ship before turret took place.)*

Plate I.



ONS

TRANSVERSE SECTIONS AT A.

Plate 11.

Admiralty
15th September 1893.
W. H. White

H. M. S. "VICTORIA".
WATER LINE SECTIONS IN VARIOUS CONDITIONS.

Scale 0 4 8 12 16 20'

REFERENCES TO TABLE BELOW.

Case I Water line is outlined in black in Fig(1) and (2)
" II Water line is shown [▥] in Fig (1)
" III Water line is shown [▥] in Fig (2)

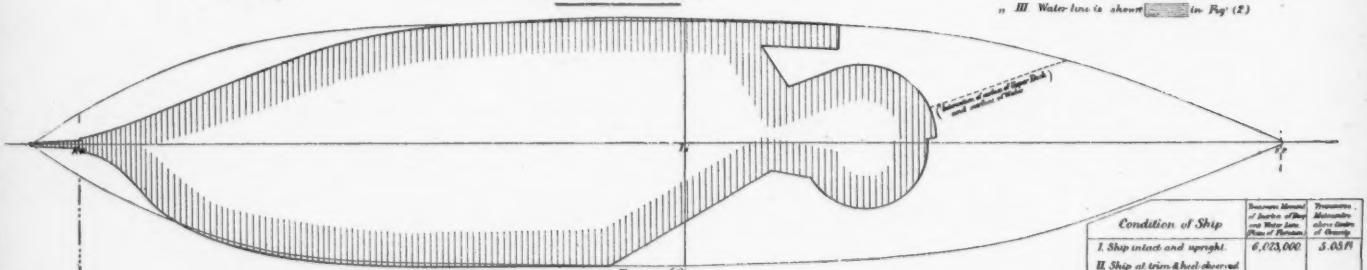


Figure (1).

Condition of Ship	Transverse Moment of Inertia of Deep and Water Lines. Plan of Flotation.	Transverse Metacentre above Centre of Gravity
I. Ship intact and upright.	6,023,000	5.05 Ft
II. Ship at trim & heel observed just before turret with water excluded from turret and battery	3,688,000	.91 Ft
III. " Ditto " but turret and battery flooded.	2,783,000	-1.84 Ft

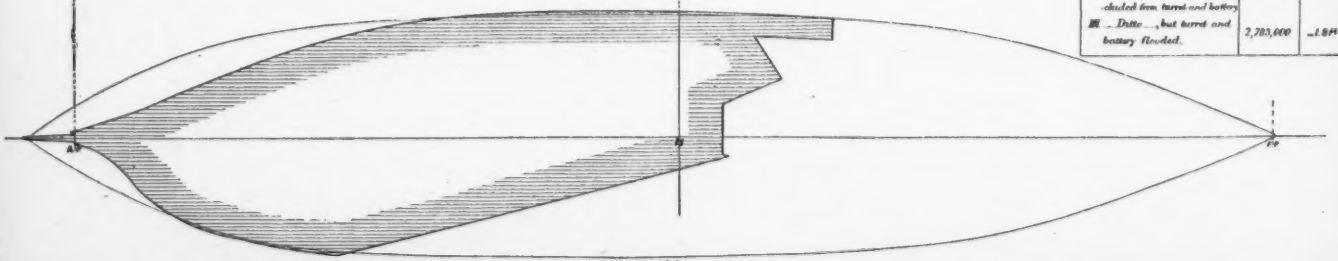


Figure (2).

less extensive, especially above water; but it must in any case have been of large extent, and have admitted very large quantities of water in a short time.

Attention has been drawn above (page 52) to the fact that the *locking* of the *Camperdown's* bow in the protective deck of the *Victoria* prevented the relative forward movement of the latter ship and reduced the tearing of the thin bottom plating by the spur of the *Camperdown*. Under the assumed condition of a non-penetrable armor belt this relative forward movement and tearing action must have taken place.

The assumption of impenetrability, however, cannot be admitted. It is in the highest degree probable that under a blow of such energy as was delivered on the *Victoria* the strongest armored side ever constructed must have yielded and been driven in. Its water-tightness and that of the bulkheads, etc., within it, adjacent to the place where the blow was struck, must have been destroyed, and the ultimate result (as regards the admission of water) would have been practically as serious under the same conditions of open water-tight doors, etc., as that which actually occurred in the *Victoria*.

There have been many instances where armor-belted ships have suffered from collision in the manner indicated. In some collisions comparatively light and grazing blows have crushed in and disturbed the water-tightness of the armored side and of the thin plating below it. In other collisions heavy blows delivered nearly at right angles have produced fatal results on belted ships. As examples, reference may be made to the well-known cases of the collisions between *Vanguard* and *Iron Duke*, and between *Grosser Kurfürst and König Wilhelm*.

In the *Vanguard* the armor was driven bodily inwards more than a foot, and the bottom plating below was torn open to the extent of about 25 square feet. This armor was only 6 to 8 inches thick, it is true; but on the other hand the force of the blow was only about two-thirds that delivered by the *Camperdown*, and the ram bow of the *Iron Duke* was not so well shaped for destroying the bottom and wing bulkheads below the armor as was the bow of the *Camperdown*. The point of the spur in

the *Iron Duke* projected forward only 2 feet before that portion of the stem which struck the lower edge of armor in the *Vanguard*. Consequently, the spur only penetrated about $3\frac{1}{2}$ feet within the *Vanguard's* side, and did not pierce the inner skin situated about $4\frac{1}{2}$ feet from the outer bottom plating. Had the *Iron Duke's* bow been shaped like the *Camperdown's*, with the spur projecting 7 feet before the vertical portion of the stem, the spur would have pierced and seriously damaged the inner skin of the *Vanguard*, and that ship must have been sunk with much greater rapidity. That she sank so slowly was entirely due to the less efficient form of the ram bow in the *Iron Duke* and to the slow passage of water into the hold through comparatively small leaks in the unperforated inner skin. Moreover, in the *Vanguard* the blow was struck at a place where the entry of water produced small change of trim, and the very slow rate of inflow of water into the hold, due to the non-perforation of the inner skin, prevented any serious heel.

In the *Grosser Kurfürst* the armor belt proved equally incapable of saving the ship. As explained above, she was moving at considerable speed across the bows of the *König Wilhelm* when the latter struck her a very heavy blow. This headway, no doubt, produced serious tearing of the bottom plating, and greater damage was done than to the *Vanguard*. The water-tight doors were open and the *Grosser Kurfürst* sank in ten minutes. Some eye witnesses alleged that she capsized in foundering.

Other cases are on record, but need not be cited, proving that the existence of an armor belt is no sufficient safeguard against injuries resulting from serious collision.

Summing up the results of the careful inquiry which has been made into the evidence given before the court martial, of which details appear in the foregoing remarks, the following broad conclusions are reached:

(1) That the interval of time which elapsed between the instant when orders were given to close water-tight doors and hatchways, and the instant of actual collision (viz., about one minute) was necessarily inadequate for the complete fulfillment

of that intention, more especially in compartments forward below the protective deck, and near to the place of collision.

(2) That although every endeavor was made to close the water-tight doors subsequently to the collision, the doors and hatchways which are proved to have remained open, permitted water to pass into compartments adjacent to those breached, and consequently greatly increased the loss of buoyancy, the depression of the bow, and the diminution of transverse stability.

(3) That, so far as can be judged, had all doors, hatchways, &c., been closed prior to the collision, the *Victoria* would have continued to retain ample buoyancy and stability, and would not have ceased to be under control.

(4) That, under the actual circumstances of the collision, and with the doors remaining open which have been enumerated above, it was inevitable that the vessel should have attained the position described by the various witnesses as reached before the lurch began, with her bow buried about 13 feet below water and with a heel to starboard of about 18 to 20 degrees.

(5) That even when so seriously injured and brought to such a critical condition had the ports in the turret and upper-deck battery been closed, the armor door secured and water excluded from turret and battery, the *Victoria* would not have capsized. It is possible that she may have eventually foundered in consequence of the gradual passage of water into compartments, respecting which the evidence leaves us in doubt.

(6) That, under the serious circumstances of this collision or of any similar accident which may occur, the safety of a ship and her continued flotation demand that provision should be made for closing gun ports and openings in upper works, through which water may pass into the interior of the ship, if the flooding of compartments produces great change of trim or serious heeling.

If such precautions are not taken the virtual height of freeboard is reduced to the height of the sills of ports or doors; and the presence of the superstructures, when water is not excluded from them, does not assist either buoyancy or stability to a sensible extent.

W. H. WHITE.

15th September, 1893.

VICTORIA AND *CAMPERDOWN*.

I.—*Speed and movements of helm and engines up to moment of collision.*

Victoria and *Camperdown*:

Speed of both ships, 8.8 knots on straight course, — Captain Bourke.

Victoria:

Helm used in *Victoria*, 35° (extreme helm), — Captain Bourke.
And was put over at 3·30¾ P. M., — Staff Com. T. H. Smith.
Port engine reversed about 3·32 P. M., when ship had turned 6 points, — Staff Com. T. H. Smith.
Starboard engine also reversed at 3·33 P. M., — Staff Com. T. H. Smith.
Collision took place at 3·34 P. M., — Staff Com. T. H. Smith.
When both engines were going full speed astern, — Staff Com. T. H. Smith.
And ship had turned 12 or 13 points, — Captain Bourke.
Ship's way was not materially checked, — Captain Bourke.
Speed was about 6 knots, or perhaps less, — Captain Bourke.
Ship's way was materially checked, — Staff Com. T. H. Smith.
Speed was reduced below 5 knots, — Staff Com. T. H. Smith.

Camperdown:

Helm used was 28° (not extreme helm), — Captain Johnstone and Lieut. Barr.
Starboard engine reversed at 3·33 P. M., — Engine-room Register and Assistant Engineer Carter.
Order to reverse starboard engine was given after turning 8 points, — Lieutenant Barr.
Port engine was stopped 3·33 P. M., — Engine-room Register and
And reversed 3·34 P. M., — W. Davies, E. R. Art.
Or 3·34½ P. M., — Assistant Engineer Carter.
The engines were put ¾ speed astern, and not full speed astern, — Engine-room Register, Assistant Engineer Carter and W. Davies, E. R. Art.
At moment of collision *Camperdown* had turned 12 points, — Admiral Markham.
Her way was not materially checked by the engines going astern, — Admiral Markham.
Speed was not more than 6 knots, — Captain Johnstone.
Speed was between 4 and 5 knots, — Lieutenant Barr.
Speed was about 5 knots, — Staff Com. T. H. Smith.
Time of collision by signal-room clock of *Camperdown*, 3·35 P. M., — Admiral Markham.

NOTE.—By engine-room clock this would have been 3 34 P. M., allowing one minute for the ship to turn four points. The latter agrees with times given by *Victoria*, and it appears there was not absolute agreement between the clocks.

Ships had advanced towards each other about 2 cables when they had each turned 6 points, — Staff Com. Smith.
Ships were about 2½ cables apart when end on to each other, — Lieutenant Barr.
Victoria turning circle just under 600 yards with extreme helm, — Captain Bourke.
But 800 yards with 28°, — Captain Bourke.
Camperdown might turn in a circle of 400 yards if inner screw put astern same time as helm was put over, — Admiral Markham.
Diameter at 10 knots with extreme helm, about 659 yards, — Captain Johnstone.

Fig. 1.

Position when signal was handed down.

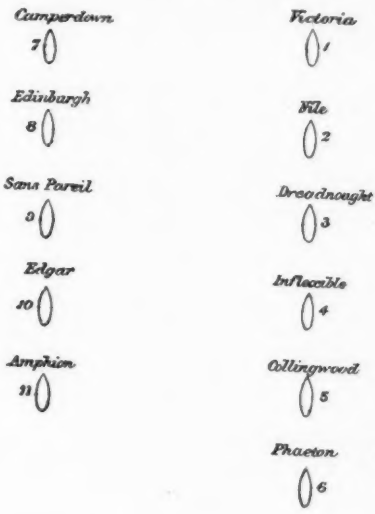


Fig. 2.

Position 3 min. after signal was made.

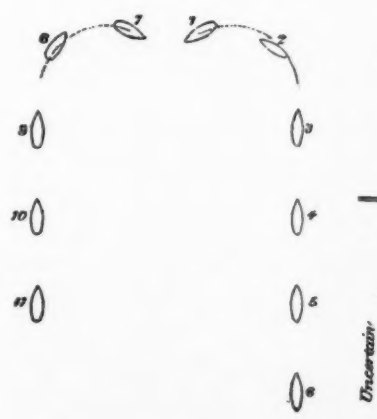


Fig. 3

Position at moment of Collision.

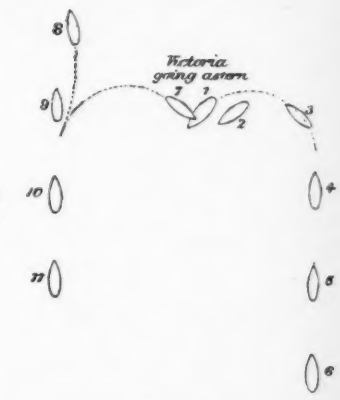
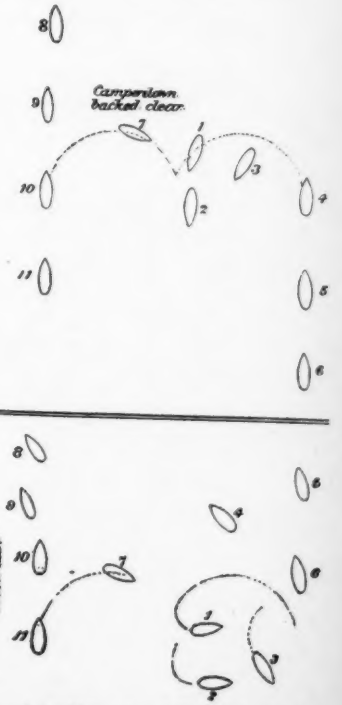


Fig. 4.

Position about 3 min. after Collision.



Approximate Position when "Victoria" Capsized.

VICTORIA.

II.—*Place and direction of blow.*

Starboard bow—20 feet before turret,	Admiral Markham.
10 feet abaft anchor bed,	Captain Bourke.
Just abaft anchor bed,	Lord Gillford.
10 or 12 feet before F. bulkhead,	Captain Bourke.
Just abaft anchor bed,	Lieutenant Barr.
2½ feet before F. bulkhead,	R. May, C. P. O.
Just before F. bulkhead,	Captain Bourke.
Bow of *Camperdown* was seen by men on fore side of F. bulkhead, but not on after side, so that she entered on fore side,	Captain Bourke.
Fore and aft lines of ships inclined at 80°,	Admiral Markham.
Camperdown struck 10 degrees before normal (1),	Captain Bourke.
Camperdown bore S.W. by S., *Victoria* bore W.N.W., so that previous statement might be modified (2),	Captain Bourke.
Struck at an angle 10 degrees less than a right angle,	Lieutenant Collins.
of 80 degrees,	Captain Johnstone.
of 7 points from stern,	Lieutenant Barr.
less than 8 points,	Lord Gillford.
of 6 to 7 points,	Staff Com. T. H. Smith.
Camperdown had turned 12 or 13 points,	Captain Bourke.
12 points,	Admiral Markham.
Victoria had turned more than *Camperdown*,	Staff Com. T. H. Smith.

(See also diagrams showing relative positions of the ships at different times.)

NOTES.—(1) Gives angle between fore and aft lines of ships 115 degrees. (2) Gives angle 78¼ degrees. See, also, note at end of Section IV.

VICTORIA AND *CAMPERDOWN.*

III.—*Behavior of ships while in contact.*

Both ships heeled to starboard at moment of impact,	Admiral Markham.
Victoria heeled slightly to starboard and settled down slightly by the bow,	Lord Gillford.
Heel of *Victoria* practically nil while locked, was carried bodily to port,	Captain Bourke.
Victoria appeared to be carried bodily to port, without heeling or changing trim,	Lord Gillford.
Did not observe either ship heel,	Captain Johnstone.
Victoria heeled slightly to starboard and settled a little by the bow,	Staff Com. Smith.
Victoria appeared to heel over two or three degrees to *port* and to be pushed bodily about a ship's breadth to port,	Captain Acland.
Victoria did not appear to heel, but was forced bodily to port,	Captain Noel.
No water on fore part of upper deck of *Victoria*,	Captain Bourke. Staff Com. Smith. Captain Johnstone.
Camperdown appeared to swing aft,	Captain Bourke.

The ships swung a little closer, but did not swing together,	Admiral Markham.
Camperdown swung two points,	Lieutenant Barr.
backed out at 20 degrees abaft the beam (3),	Captain Bourke.
at same angle as she went in,	Captain Johnstone.
at five points from stern,	Lieutenant Barr.
cleared in one or two minutes,	Admiral Markham.
in one minute,	Lord Gillford.

NOTE.—(3) Giving angle of swinging while in contact 45 degrees. See, also, note at end of Section IV.

VICTORIA.

IV.—*Extent of damage.*

Upper deck was ploughed into, broken and set back towards midships,	Captain Bourke.
Starboard anchor bed was not injured (the anchor remained in its place),	Staff Com. Smith.
Shock of collision was heavy, but not enough to throw witness down,	Lieutenant Heath.
Woodwork and, presumably, part of ironwork of upper deck was piled up at inner end of cut,	Lieutenant Heath.
Stem went in 8 or 10 feet, cutting through and splintering upper deck,	Lieutenant Collins.
Appeared to crunch up the deck nearly to the center line, the fracture being some distance ahead of the stem of *Camperdown*,	Admiral Markham.
Upper decks of the two ships were about the same level, stem went in 8 or 10 feet, making a very clean hole,	Captain Johnstone.
Went in 8 or 10 feet, crunching up the forecastle and splintering it right up,	Lieutenant Barr.
Saw crash, with some splinters flying, and heard a noise,	Captain Acland.
Did not see collision, but heard the crash,	Captain Moore.
Went in 10 or 11 feet, and wood deck was splintered in every direction,	Captain Bourke.
Bulkhead at F. (23) was damaged between upper and main, and between main and protective decks. Bulkhead at E. (22) below protecitve deck was damaged, and the blow probably disturbed the bulkheads and decks in the vicinity,	Captain Bourke.
Ship came through 2½ feet from, and damaged F. bulkhead,	R. May, C. P. O.
F. bulkhead appeared to buckle up,	R. May, C. P. O.
Closed starboard door in F. bulkhead one minute after collision, but did not see *Camperdown's* bow,	J. Thompson, A. B.
Thinks following bulkheads were damaged:	
On lower deck.—F. (23), between No. 1 and Nos. 3 and 5 bunkers; also starboard chain locker bulkhead,	Captain Bourke.
On platforms.—E. (22),	Captain Bourke.
Below platforms.—E. (22), and fore and-aft bulkhead from 12 to 22 at middle line, and from 22 to 31 at side,	Captain Bourke.

Marks on *Camperdown* are 9 feet from bow at upper deck. Extreme limit of hole on port side is 15 feet 3 inches from point of ram. Mr. Newnham.

NOTE.—The weight of evidence above shows that the *Camperdown* struck at an angle of 10 degrees abaft the beam, and backed out at 30 degrees abaft the beam. The swinging through 20 degrees probably caused the deformation of the stem, and the injury to the bow plating of that ship. Mr. Newnham, chief constructor at Malta, who was not in possession of the above evidence, concluded, from an examination of the *Camperdown* in dock, that she struck at a considerable angle *before* the beam, which was contrary to the weight of evidence. He also shows her backing out on the beam instead of at 30 degrees abaft the beam. (See Question 1837 and drawings put in by Mr. Newnham.) As will be seen by the plans, this difference of 30 degrees is of considerable importance in regard to the size of the hole in *Victoria*.

Mr. Newnham allows 2 feet all round for extension of breach by swinging. On Plates III to VI attached, the *Camperdown* is placed at the maximum distance into the *Victoria*, indicated by the damaged plating on the former, and the positions of the ship at 10 and 30 degrees abaft the beam are marked, giving a fairly exact method of determining the probable area of breach. From Mr. Newnham's report it would appear that at the level of the upper deck the marks of contact are at a maximum distance of 9 feet from stem-head of *Camperdown*. If this be accepted as the limit, the extent of the damage would be *less* than has been shown on the drawings prepared at the Admiralty, and very considerably less than on the drawings prepared at Malta, which show the *Camperdown* run in for a distance of 12 feet measured along her side at the main deck, and a distance of 11 feet measured along a fore-and-aft line in *Camperdown*, which is placed at right angles to the fore-and-aft line in *Victoria* instead of at an angle of 60 degrees to it.

VICTORIA.

V.—*Condition as to heel and trim after Camperdown cleared.*

Appeared to be settling down by the head; a few minutes after heeled over to starboard, Admiral Markham.

Water seemed to pour in on the forecastle at once, Admiral Markham.

As the forecastle went under there was a proportionate rise of the stern, Admiral Markham.

Began to settle forward visibly, and heeled slowly but increasingly to starboard, Captain Bourke.

Heel increased gradually and evenly up to about 20°, Captain Bourke.

Gradually filled by the bow and heeled to starboard, Staff Commander Smith.

Heeled slowly to starboard and settled by bow, so that in four or five minutes water came through hawse pipes, and in six or seven minutes covered starboard side of forecastle before the redoubt, Staff Commander Smith.

Water rose quickly over forecastle, the ship gradually heeling more and more over to starboard, Lord Gillford.

Water was up to hawse pipes in three minutes, when water nearly reached redoubt. The men near bower anchor were up to their waists in water, Lord Gillford.

And the water line crossed the deck at an angle of 45°, Lord Gillford.

The heel increased gradually and steadily from the beginning up to the lurch, Lord Gillford.

Settled down by bows and heeled to starboard, Lieutenant Heath.

The water was over the upper deck in about four minutes, Lieutenant Heath.

Heel increased gradually up to 20°, — Lieutenant Heath.
As ship went ahead she heeled more and more to starboard, — Lieutenant Barr.
Heeled over about 4° or 5°, and forecastle went under water, — Captain Acland.
Retained this heel for about ten minutes, then lurched to 35° or 40°, — Captain Acland.
Had a heel of about 8°. As ship went ahead heel increased to about 18°, or possibly 20°, — Captain Moore.
The ship was very much by the head, and as she turned her head still went down, — Captain Moore.
The stern did not rise much; did not see starboard propeller, — Captain Moore.
Had heel of about 8° in two or three minutes. This gradually increased to 18° or 20° within four or five minutes of collision, — Captain Moore.
As ship went ahead heel increased, and bow went down continuously for about 10½ minutes, when heel was certainly not more than 20°, — Captain Noel.
Bow gradually settled down, and heel gradually increased, — Captain Wilson.
Bow gradually settled down until the ship lurched, — Captain Custance.
Not sure that she gave two lurches, — Captain Custance.
Heeled steadily over to starboard until turret reached the water, — Rear Admiral Vander-Meulen.

VICTORIA.

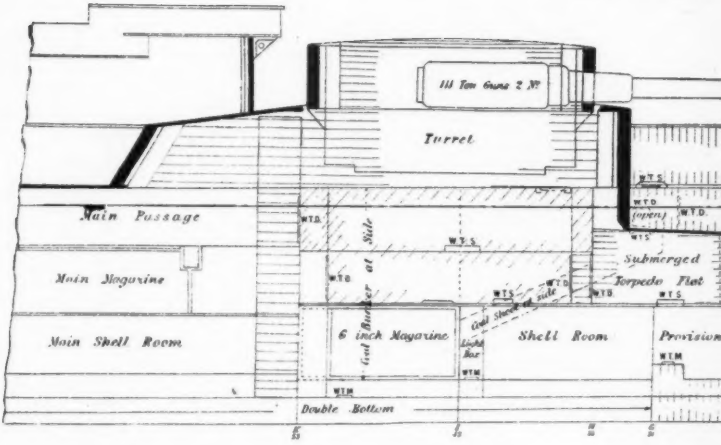
VI.—*Condition as to heel and trim just before lurch took place.*

Heel before lurch was 10 to 15 degrees, — Admiral Markham.
Bow was very greatly depressed. Heel was not more than 20 degrees, because officers and men were able to keep their feet, — Captain Bourke.
Heel was not more than 20 degrees. There was no difficulty in walking without holding on, — Captain Bourke.
Water was up over glacis and washing into turret ports, — Staff Commander Smith.
Men worked at windlass covers till up to their middles in water, — Staff Commander Smith.
Capstan was under water, — Staff Commander Smith.
Turret guns remained fore and aft, — Staff Commander Smith.
Had no difficulty in standing before lurch, — Staff Commander Smith.
The heel was under 20 degrees, — Staff Commander Smith.
Lost his footing when ship lurched, — Lord Gillford.
Water was up to turret ports 30 or 45 seconds before lurch, — Lord Gillford.
The turret guns remained fore and aft, — Lord Gillford.
Heel was about 20 degrees, — Lieutenant Heath.
Estimated 20 degrees because he could stand without assistance, — Lieutenant Heath.
Turret guns remained fore and aft, — Lieutenant Heath.
The whole of the port screw was out of water, — Lieutenant Barr.
Heel was about 4 or 5 degrees, and forecastle was under water, — Captain Acland.
Ship remained at heel of 18 to 20 degrees for four or five minutes before lurch. Bow was under water. Water was half way up turret, half way up battery door, and 6-inch gun ports were awash, — Captain Moore.

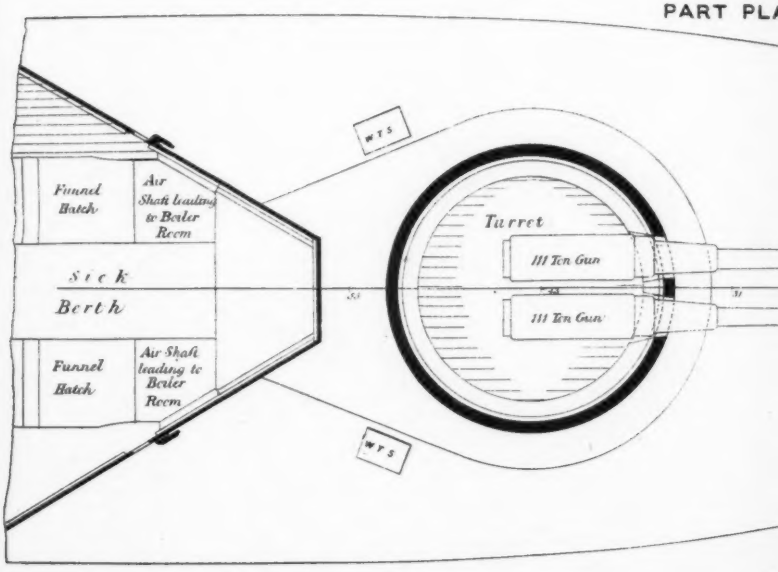
H. M. S. "VICTO

PART PROFILE

Scale 0 4' 8' 16'



PART PLA



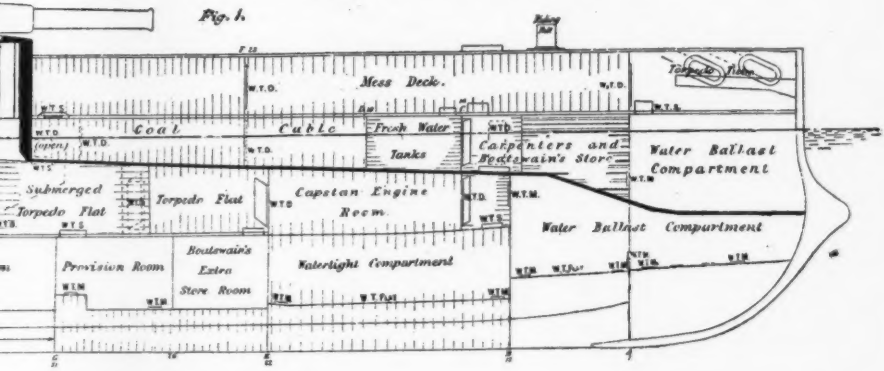
"VICTORIA".

PROFILE.

Condition:-

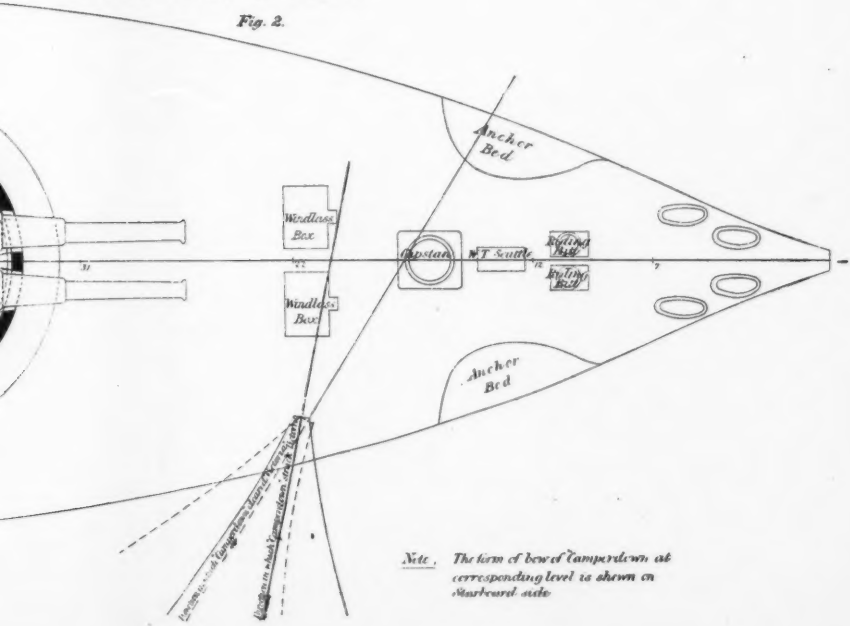
- Inevitably flooded through damaged side, decks and bulkheads.
- Subsequently flooded through open doors, hatches and ports.
- Probably filled after riding bitts were submerged.
- Some of these may have been flooded, evidence is not clear.

Fig. 1.



PART PLAN OF UPPER DECK.

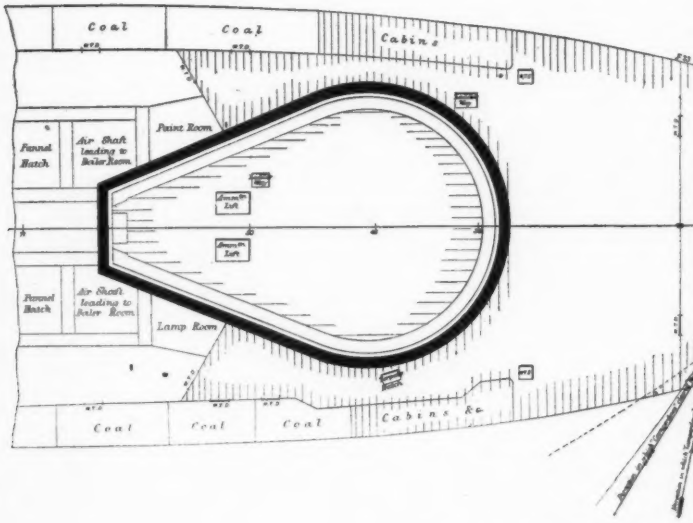
Fig. 2.



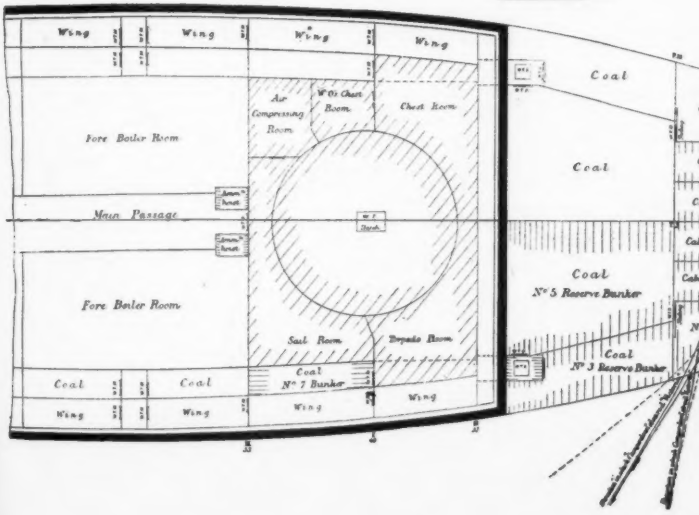
Note. The form of bow of Camperdown at corresponding level is shown on starboard side

H. M. S "VICTORIA".

PART PLAN OF MAIN DECK.



PART PLAN OF LOWER DECK



MAIN DECK.

Plate V.

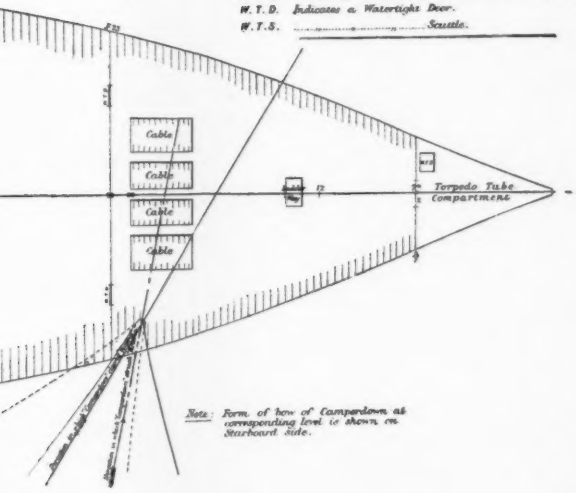
Condition.

Initially flooded through damaged side, decks and bulkheads.

Subsequently flooded through open doors, hatches, and ports.

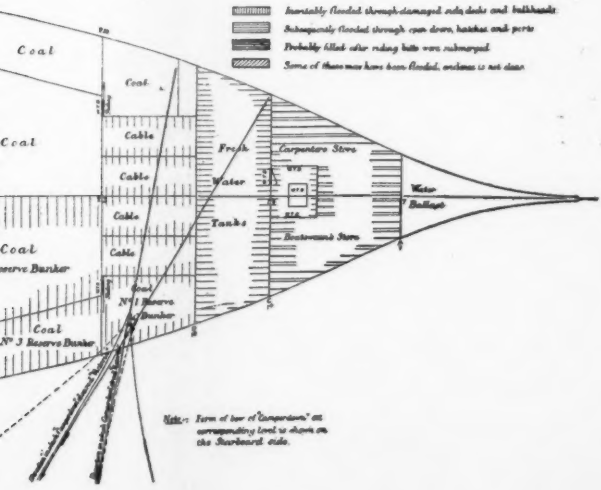
W.T.D. Indicates a Watertight Door.

W.T.S. ..... Scantle.



Note: Form of bow of Camperdown at corresponding level is shown on Starboard side.

WER DECK



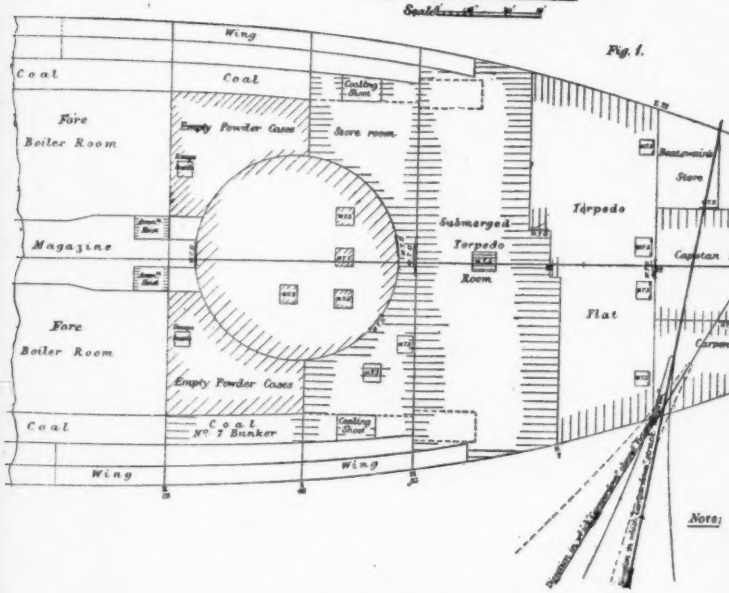
Note:- Form of bow of Camperdown at corresponding level is shown on the Starboard side.

H. M. S. "VICTORIA".

PART PLAN OF PLATFORMS.

Scale 1' 0" 2' 0" 4'

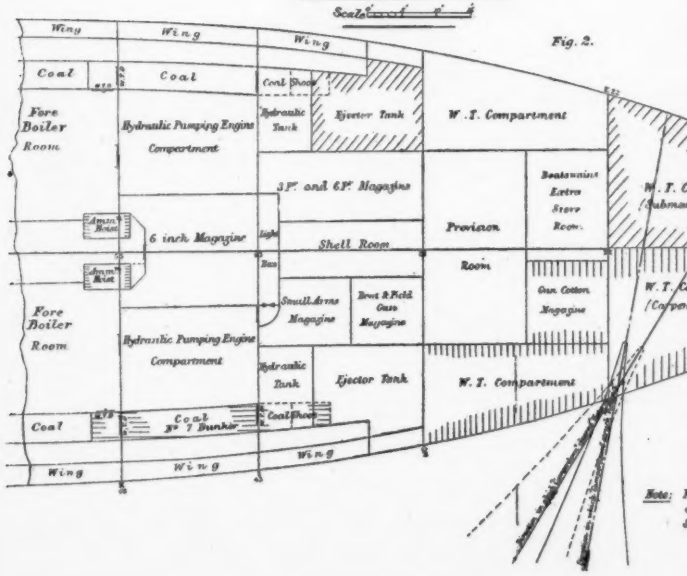
Fig. 1.



PART PLAN OF HOLD.

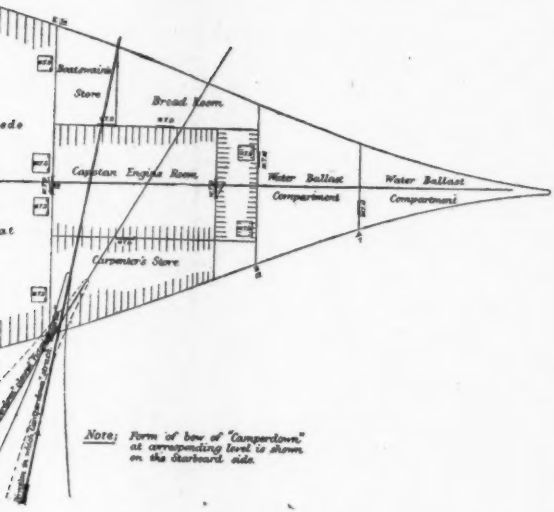
Scale 1' 0" 2' 0" 4'

Fig. 2.



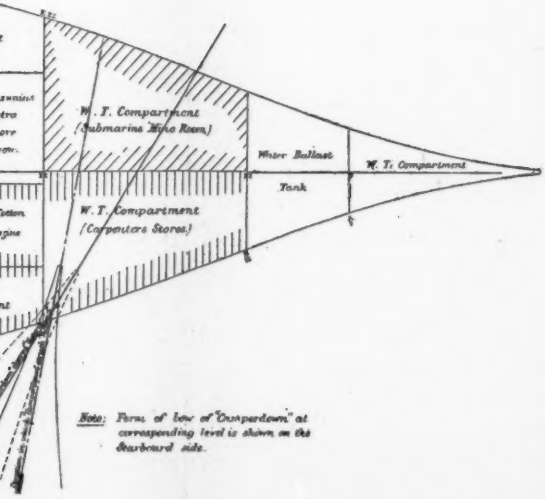
Initially flooded through damaged side, decks and bulkheads.
Subsequently flooded through open doors, hatches and pore.
Flow may have been flooded, evidence is not clear.

Fig. 1.



Note: Form of bow of "Camperdown" at corresponding level is shown on the Starboard side.

Fig. 2.



Note: Form of bow of "Camperdown" at corresponding level is shown on the Starboard side.

TRANSVERSE SECTION OF "VICTORIA" AT STA

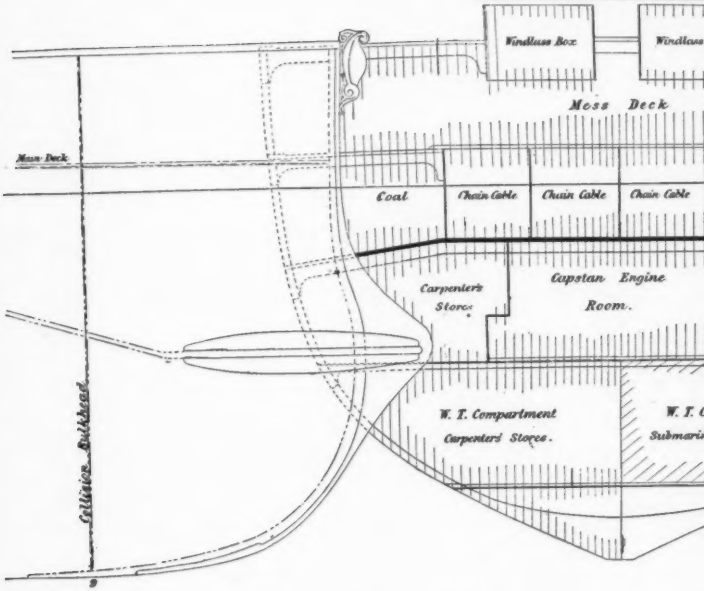
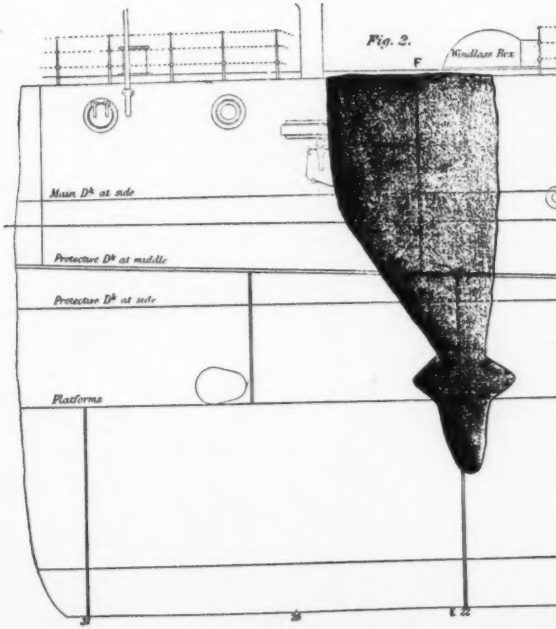


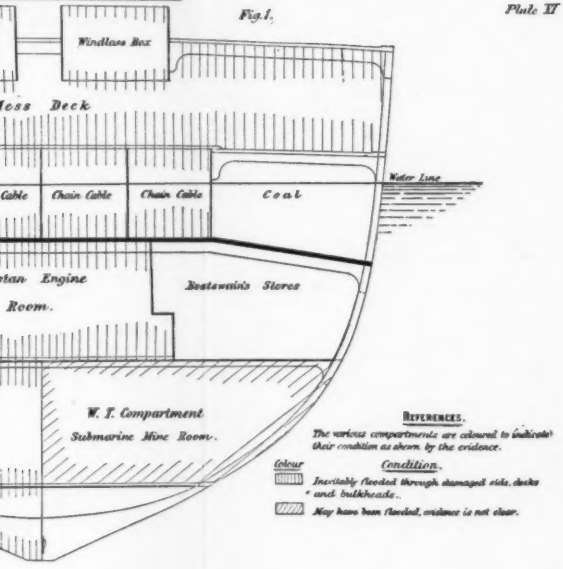
Fig. 2.



N OF "VICTORIA" AT STATION 22.

Fig. 1.

Plate XI



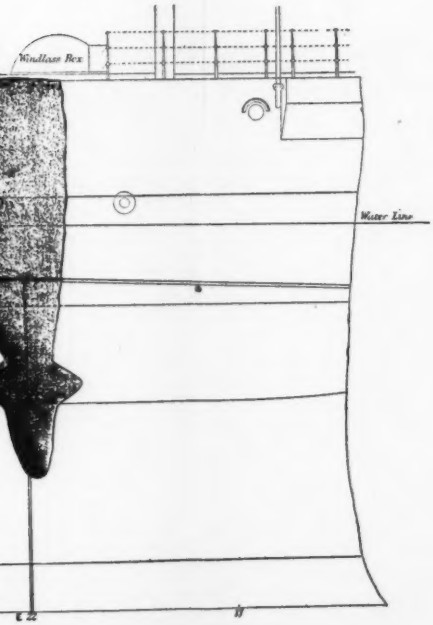
REFERENCES.

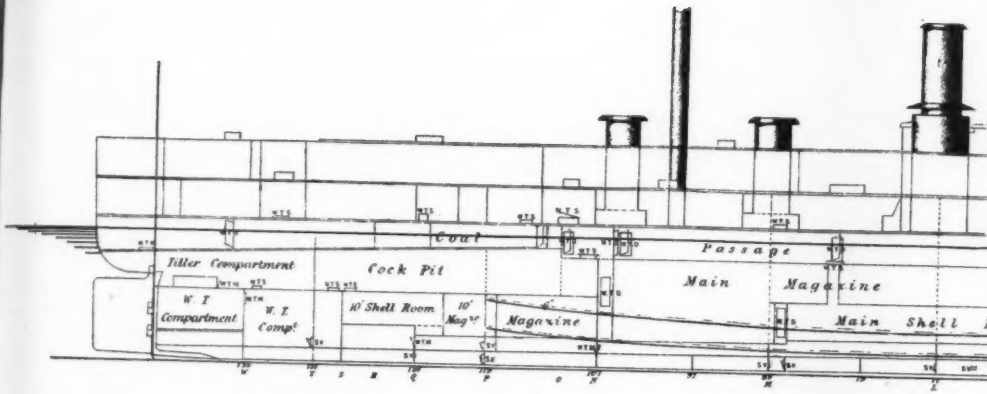
The various compartments are coloured to indicate their condition as shewn by the evidence.

Colour — **Condition.**

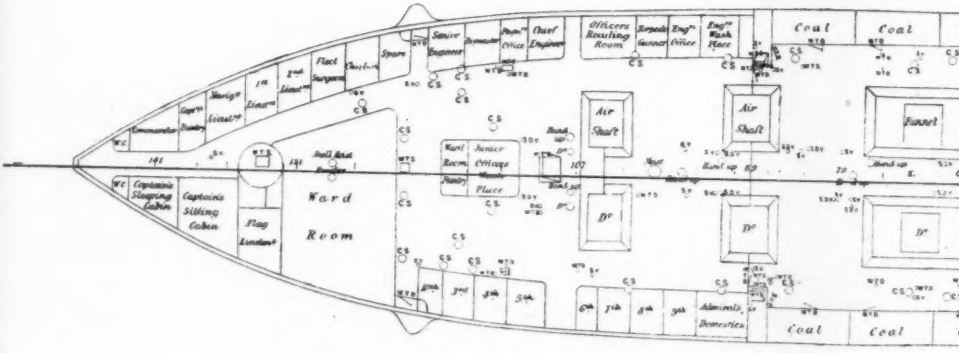
Inevitably flooded through damaged side, decks and bulkheads.

May have been flooded, evidence is not clear.





MAIN DECK.



LOWER DEC

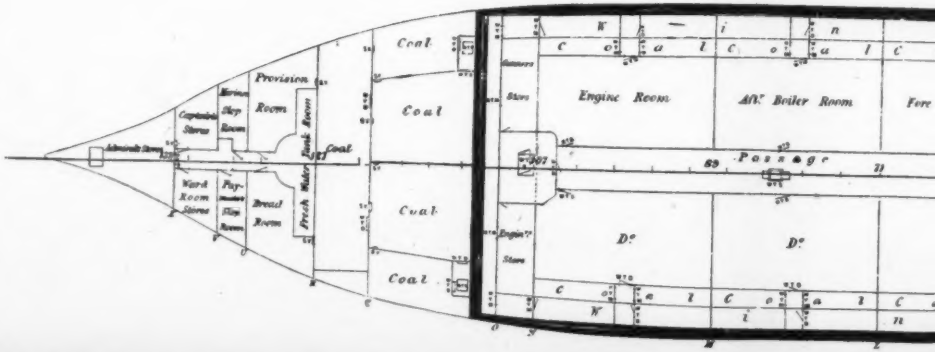
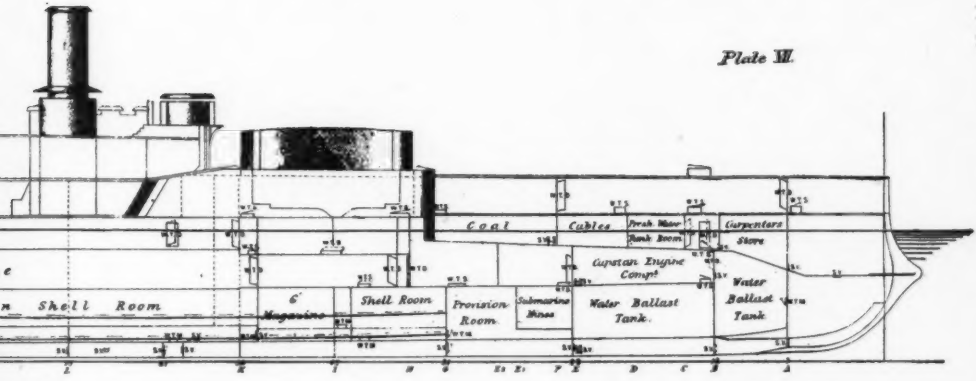
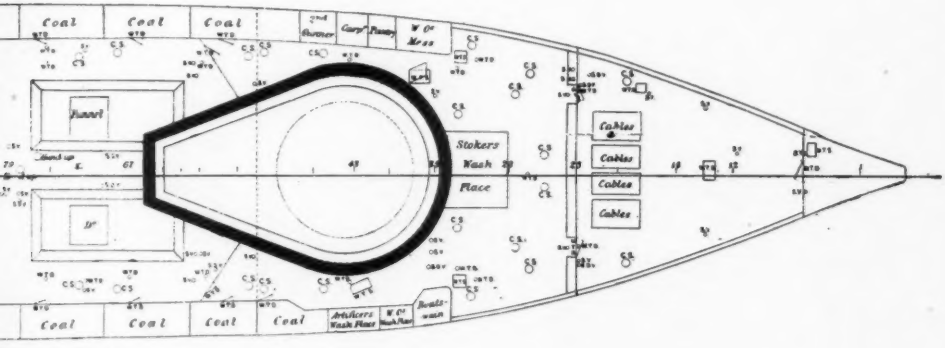


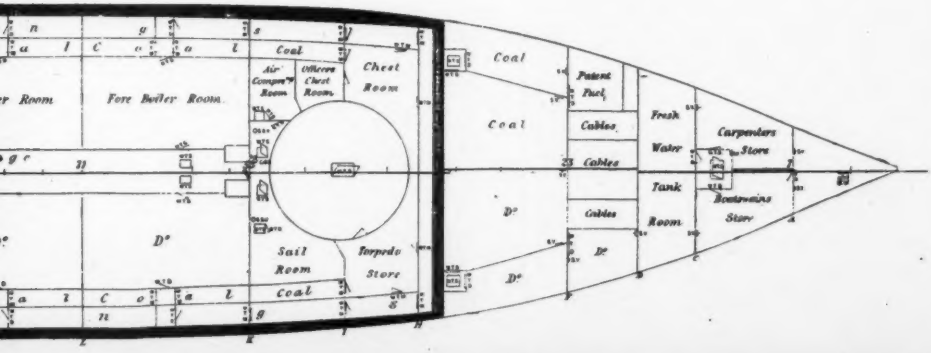
Plate M.



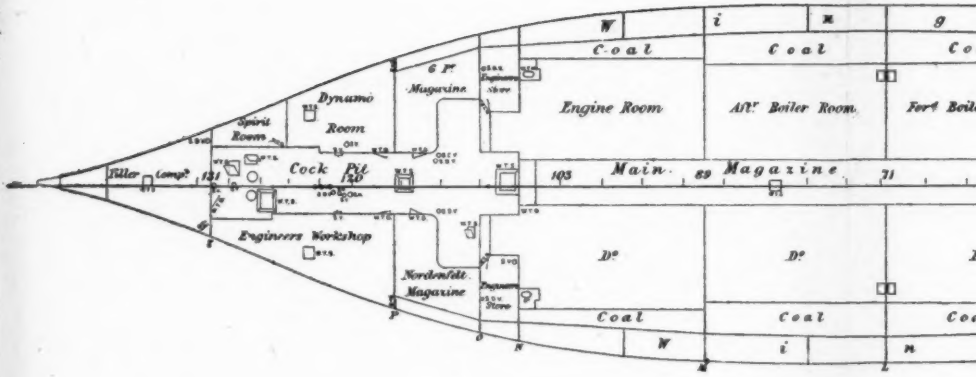
AIN DECK.



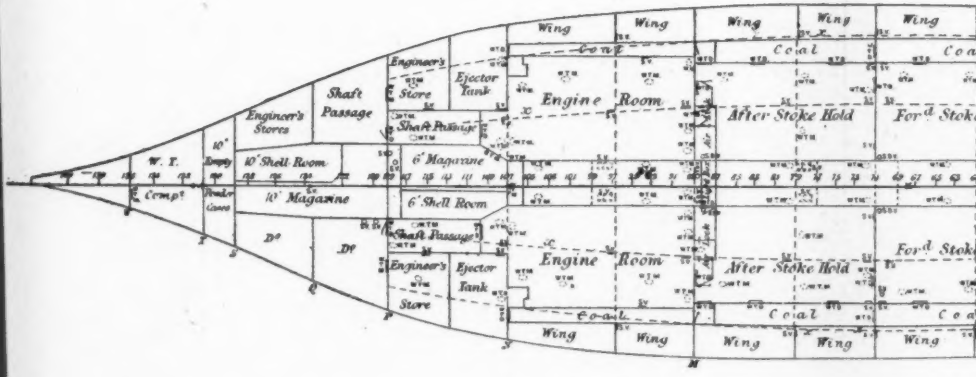
LOWER DECK.



PLATFORMS.

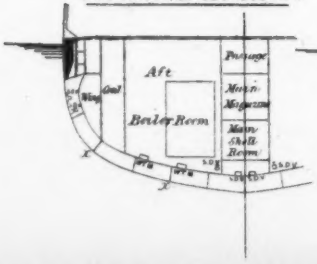


PLAN OF HOLD.



SECTIONS

SECTION AT 85 LOOKING AFT



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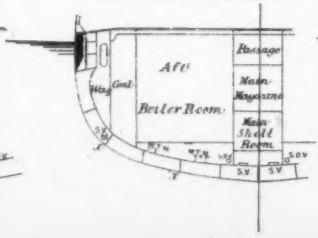

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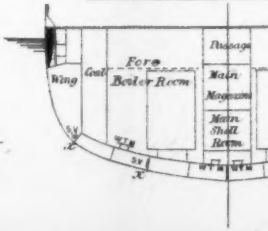
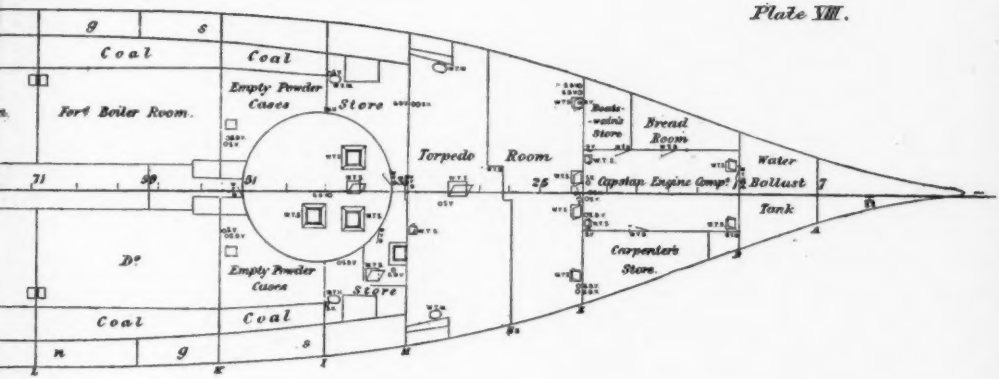
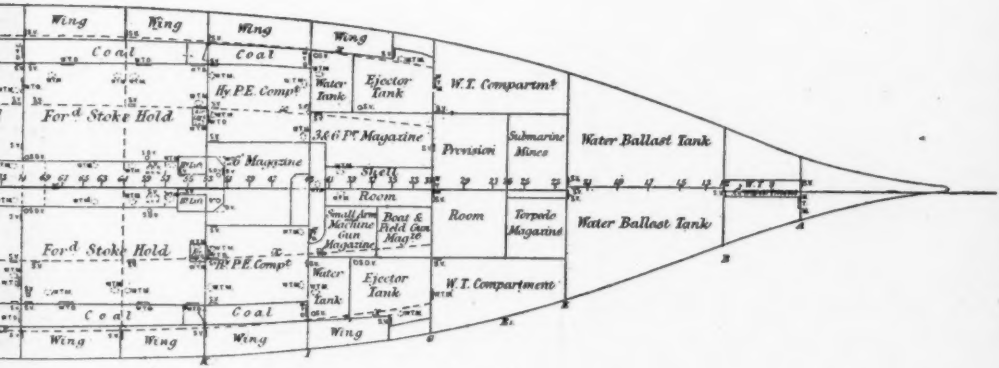


TFORMS.

Plate VIII.

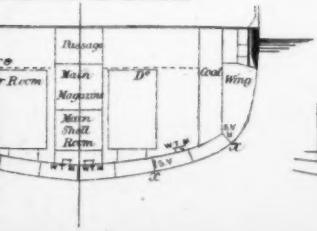


OF HOLD.

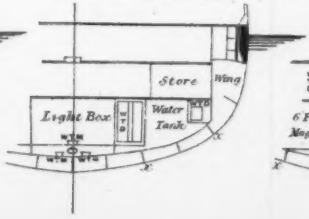


SECTIONS

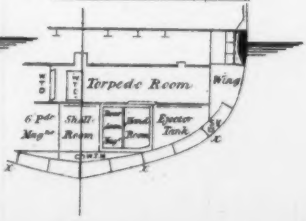
AT 61 LOOKING FOR.D



SECTION AT 43 LOOKING FOR.D



SECTION AT 35 LOOKING FOR.D



The turret guns remained fore and aft, — Captain Moore.
Traced water line on model thus: half way up turret, half way up battery door, along the sill of the two foremost 6-inch gun ports, and just below glacis of embrasure port on starboard quarter; not sure that he saw the glacis, — Captain Moore.
Went out through screen to 10-inch gun, saw port propeller coming out of water, lower blades still touching the water, — Fleet Surgeon Ellis.
Heel was not more than 20°, and water was 2 or 3 feet deep up the sides of the turret, — Captain Noel.
Bow was entirely immersed up to turret, heel was about 18°, and water was washing against the battery bulkhead, — Captain Noel.
Did not observe battery ports or doors, — Captain Noel.
Turret guns remained fore and aft, — Captain Noel.
Heel from 10° to 12°, — Captain Wilson.
Port screw was not out of water, — Captain Wilson.
Did not observe gun ports, — Captain Wilson.
Step of turret was in the water, — Rear-Admiral Vander-Meulen.
Port screw was partly out of water, — Rear-Admiral Vander-Meulen.
Ship was down by the head with half the forecastle under water, heel was about 15°, — Captain Jenkings.

Upper Deck—

Turret and redoubt:—Turret ports open, — Captain Bourke.
Water through turret ports would pass into the turret well, through the turret doors, and so into the redoubt, — Captain Bourke.
6″ gun ports, battery doors and side scuttles.—Nearly all the side scuttles and gun ports were open when manœuvres began, — Captain Bourke.
Thinks they were never closed, — Captain Bourke.
Armored doors in screen bulkhead were also open when manœuvre began, — Captain Bourke.
Thinks they were never closed, — Captain Bourke.
The after gun ports were certainly open, — Captain Bourke.
Orders were given to close the gun ports in battery, but doubt whether there was time to close them. They were certainly open up to that time; just before lurch, — Lieutenant Heath.
No knowledge of any attempt to close the doors in the screen bulkhead, — Lieutenant Heath.
Gave orders to close the starboard door in screen bulkhead, but almost certain men did not have time to do it, — Lieutenant Collins.

Main Deck—

Bow tube compartment from stem to bulkhead 7.—Went into the fore compartment (called the bow tube compartment), and assisted in closing the scuttles, one on either side . . . Then closed the door that led into the bow tube compartment, — R. May, C. P. O.
Closed the door a minute after the collision, — R. May, C. P. O.

Fore mess-deck, 7 to 23.—Bow of *Camperdown* was seen by men in fore mess-deck, so that *Camperdown* must have entered before the dividing bulkhead, Captain Bourke.

Stokers' mess deck, from 23 to the angle bulkheads, excluding coal bunkers at side.—As ship heeled over and settled down there was nothing to prevent the water from covering the whole of the fore mess deck, as far aft as the foremost W. T. door in bulkhead abreast after part of redoubt, Captain Bourke.

Saw doors were closed on the stokers' mess deck, T. Smith, Artificer.

Saw water coming through what he thought was probably the bulkhead door on the starboard side of the stokers' mess deck. Not sure whether it came from joints of door or bulkhead, T. Smith, Artificer.

Helped to close starboard door between stokers' and seamen's mess deck. Also door to same flat to after end of stokers' mess deck. Did not see *Camperdown's* bow, J. Thompson, A. B.

Closed the door on the fore mess deck between the stokers' and fore mess deck on port side. A little water came through clamps when I left it, A. Blackman, A. B.

Saw the port foremost door leading to mess deck, and port and starboard doors leading to bag rack flat closed, G. Sheriff, P. O.

Protective or lower deck—

Water-ballast compartment from stem to bulkhead, 7.—Hatch to this compartment closed after collision, R. May, C. P. O.

Sure of this, R. May, C. P. O.

Believes this compartment was perfectly tight, Captain Bourke.

Boatswain's store, starboard side, 7 to 14.—Hatch leading to warrant officers' store rooms was closed, but not properly secured; only about two flys put on it, R. May, C. P. O.

Door to this store room believed to be closed, Captain Bourke.

This compartment would be eventually flooded through the riding bitts, Captain Bourke.

Closed the door to the boatswain's store room on the afternoon of the collision, about three minutes after the collision. Put all clips on he could possibly get to work; thinks more than one-half. Was in boatswain's store at time of collision, C. Bould, A. B.

Carpenter's store, port side, 7 to 14.—Hatch leading to the warrant officers' store room was closed, but not properly secured; only about two flys put on it, R. May, C. P. O.

Door to store believed to be closed. This store would be eventually flooded through the riding bitts, Captain Bourke.

Fresh-water tank, 14 to 18.—Hatch leading to tank room was closed, but not properly secured; only about two flys put on it, R. May, C. P. O.

It is not certain that the tank-room door was closed, so that water would enter tank through armored hatch. Would be eventually flooded through riding bitts, Captain Bourke.

Cable lockers and coal bunkers, 18 to 23.—No. 1 bunker was full of coal and open to the sea. Starboard sheet chain locker would be full, as the bulkhead was probably damaged, Captain Bourke.

Coal bunkers from station 23 to armor bulkhead.—No. 3 reserve bunker was full of coal, as were all the other reserve bunkers, to the best of his belief, Captain Bourke.

No. 3 was opened to the sea by the blow, since bulkhead F. 23 was crunched in, Captain Bourke.

F. 23 was probably so damaged as to allow water to get into No. 5 bunker, Captain Bourke.

Did not know whether door from No. 3 reserve bunker to the pocket at head of coal shoot was closed or not, Lieutenant Heath.

Air-compressing room, port side.—No direct evidence to show that door to this was closed, Captain Bourke.

Sail room, chest room and torpedo store, with turret support.—No direct evidence that the hatch leading from turret support was closed. It was closed once, but opened again to let a man out, Captain Bourke.

Armored hatch on port side of stokers' mess deck; saw them about closing that as he came by, T. Smith, Artificer.

Platforms—

Compartment fore end of capstan-engine room.—Water from the capstan flat could go forward through the door of the small bulkhead put into the ship at Malta. There is no evidence that this door was closed. The compartment between the capstan-engine flat and B. bulkhead up to the armored deck was full, Captain Bourke.

Capstan-engine room.—Was full of water, no evidence to show that the door between this and the submarine mining flat was closed, Captain Bourke.

Bread room, port side.—Closed and probably not damaged by shock, Captain Bourke.

Saw door to bread room in capstan-engine flat locked in the morning after the rounds. Saw all the water-tight clips put down, W. Johnson, P. O.

Boatswain's store, port side.—Closed and probably not damaged by shock, Captain Bourke.

Closed the door of boatswain's store room properly before the collision in the forenoon, C. Bould, A. B.

Carpenter's store, starboard side.—Carpenter's store was full, Captain Bourke.

Torpedo flat, 22 to 27 (afterwards called the submarine mining flat).—No evidence to show that the door between this and the capstan-engine flat was closed, so that water could pass into the submarine mining flat through E. 22. If, as I believe, E. 22 was damaged, water would go direct into the submarine mining flat, Captain Bourke.

When closing the door in E. 2 bulkhead, saw water in the submarine flat; would not be certain whether water was coming through the door in E. 22, or from the side somewhere. Could not go farther because of the water, C. A. Jacobs, P. O.

Submerged torpedo room.—Closed the door at the fore end of the submarine flat—that would be at the after end of the submarine mining flat. Closed it properly, not more than one minute after the collision. Would not be certain that every clip was on, C. A. Jacobs, P. O.

Saw any amount of water in the submerged flat when trying to close the door in H. bulkhead. Thought it seemed to be coming from somewhere through the midship part of the foremost bulkhead, R. H. Ruff, A. B.

Compartments between 35, the ring bulkhead, and 43.—Tried to close the sliding door in H. bulkhead in submerged torpedo flat; closed it from 6 to 8 inches, when the door suddenly brought up, could not move it one way or the other, R. H. Ruff, A. B.

Space for empty powder cases between I. and K. bulkheads.—Saw the water-tight flap between the upper torpedo room and the submerged flat, closed it himself, W. Hainen, Leading Stoker.

Saw the hatch to the magazine flat in turret support flat closed. R. H. Ruff, A. B.

Assisted to lower the horizontal hatch down, but did not secure hatch, did not know there were any securing bolts. Referred to the large hatch in the center of the turret-support flat at the top of the ladder leading to magazine flat, J. Hennessy, A. B.

Hold—

Water-tight compartment, from stem to 7.—Believes this was perfectly tight, Captain Bourke.

Saw the manhole in A. bulkhead properly closed in the morning, between 6 and 8. Refers to the lower manhole in A. bulkhead, A. E. Churchill, A. B.

Water-tight compartment, 7 to 12.—Always kept locked; door could not be open while hatch to submarine mine stores was open, Captain Bourke.

Saw water chamber door was closed in B. bulkhead on day of collision. Could not be opened without my knowing it. Kept key myself, Salvo Tabona, Bumboatman.

Water-tight compartment starboard side, 12 to 22.—This was damaged by blow, Captain Bourke.

Closed hatch of starboard water-tight compartment under capstain engine-room flat, properly, about half-past two in the afternoon, J. Marchant, Painter.

Water-tight compartment below, from 12 to 22, starboard side.—Considers ship full below the platform deck between 12 and 31, with the possible exception of compartment known as the old submarine mine room, and the small wing compartment beyond it, Captain Bourke.

Water-tight compartment port side, 12 to 22.—Hatch to this compartment was generally open, the compartment being in constant use. Standing orders to close the hatch when men were not working there. This hatch might have been closed, it was not seen after the collision, Captain Bourke.

Abaft B. 12, thinks it is possible that the fore-and-aft bulkhead to the water-tight compartments remained water-tight, but is of opinion this bulkhead was rendered not water-tight by the tremendous blow, Captain Bourke.

I believe, seeing that it was Thursday afternoon, no one was in the compartment; and, if so, I can only reiterate my belief that the hatch was closed, Captain Bourke.

Water-tight compartment starboard side, 22 to 31.—Considers ship full below the platform deck between 12 and 31, with the possible exception of the compartment known as the old submarine mine room and the small wing compartment beyond it. Starboard water-tight compartment abreast provision room damaged, Captain Bourke.

Water-tight compartment port side, 22 to 31.—Cannot say if the port water-tight compartment was full or not. The hatch to it was closed, Captain Bourke.

Saw hatch to water-tight compartment, port side, abaft E. bulkhead, closed on that morning, Lieutenant Heath.

Submarine mine room (used as extra boatswain's store-room).—Had been fitted as a submarine mining room; now fitted as boatswain's extra store room . . . . and door generally kept closed, Captain Bourke.

Closed the hatch to the old mining room properly, after Captain went his rounds in the forenoon, C. Bould, A. B.

Torpedo magazine, or guncotton magazine.—Thinks guncotton magazine full of water in consequence of blow probably damaging bulkhead between this compartment and the starboard water-tight compartment 22 to 31, Captain Bourke.

Saw hatch to guncotton magazine abaft E. bulkhead closed on morning of collision, Lieutenant Heath.

Provision room.—The bulkhead dividing this from the starboard water-tight compartment was probably damaged by blow, Captain Bourke.

Closed hatch to provision room between 9 and 10 in the morning, and screwed it well down; hatch was never opened without my being there. Saw all the water-tight clips put on, W. Johnson, P. O.

Compartment below provision room, &c., 22 to 31.—Considers the ship full below the platform deck between 12 and 31, with the possible exception of the compartment known as the old submarine mine room and the small wing compartment beyond it, Captain Bourke.

Ejector tank, starboard.—Hatch to starboard ejector was closed when the rounds were going, Lieutenant Heath.

Ejector tank, port.—Did not know if the hatch to port ejector tank was closed at time of collision. Believed it was, as the men who were probably working there at the time of collision would come out and shut the hatch, W. H. Rawlinson, Engineer.

If double-bottom party were down there at the time of collision, they would have directly come up, and, I presume, have closed the hatch. If, as is probable, the stoker double-bottom party were not at work, but having their "make-and-mend clothes" day, then I cannot but think that the hatch was closed properly, as the men would not be again going down there until the next day, Captain Bourke.

No. 7 bunker in wings, starboard side.—Bunker empty. The horizontal door in armored deck to incline shoot open, as also door from No. 5 to the little square place on the plan. Men working in shoot at time of collision. No evidence that door from No. 5 to shoot was closed, and it is almost certain that the horizontal door was not closed, Captain Bourke.

Cannot say if coaling shoots from armored deck forward to side bunkers were closed and secured in a water-tight manner prior to or after the collision. Knows that the horizontal sliding door leading from No. 5 to No. 7 bunker was open before the collision. Believes door from No. 3 to head of shoot was closed, W. H. Rawlinson, Engineer.

Left No. 5 reserve bunker about 3 o'clock, when door was not shut, two men being in bunker; does not know whether these men ever came out. Sliding door to shoot could not be closed from the pocket, A. E. Neale, Stoker.

Hydraulic-engine rooms, starboard and port.—Put clips on the starboard hatch. Did not close port hatch. The engineer officer—one of those drowned—was at the port hatch, J. Hennessy, A. B.

Does not think water penetrated to the hydraulic rooms, Captain Bourke.

H.M.S. *VICTORIA*.

Admiralty Minute on the question of closing the watertight doors, and on the construction and stability of the ship.

1. The Lords Commissioners of the Admiralty in their Minute, dated 28th October, 1893, on the finding of the court martial which inquired into the loss of Her Majesty's ship *Victoria*, have stated that the question of closing the watertight doors of the *Victoria* and the construction and stability of that ship would be dealt with separately; this Minute is therefore promulgated.

The finding of the court martial concluded with the following words: "The court has placed in the minutes all evidence obtainable with regard to the closing or otherwise of the water-tight doors of Her Majesty's ship *Victoria*, but it does not feel itself called upon, nor does it feel itself competent, to express an opinion as to the causes of the capsizing of the *Victoria*."

Consequently, on receiving the minutes of evidence, their Lordships instructed the Director of Naval Instruction to make a thorough examination and analysis of those parts of the evidence which throw light on these points. The report which he accordingly prepared (dated the 15th September and published herewith) has been carefully considered by their Lordships, with the evidence on which it is based. They find that this evidence is ample, notwithstanding the fact that many officers and men who would have been valuable witnesses were unhappily lost in the disaster.

2. Their Lordships have thus been able to complete a full investigation into the causes of the sinking of the *Victoria* and to arrive at the definite conclusions hereinafter set forth.

3. The evidence establishes the following facts:

(*a.*) That after the collision the fore part of the *Victoria* gradually sunk and the ship simultaneously heeled to starboard, and that after this had been going on a short time a lurch occurred which resulted in the capsizing of the ship.

(*b.*) That up to a very short time (about one minute) before the collision took place a large number of watertight doors, hatches, and ports were open, and that, owing to the inrush of

water, many of these, situated in the forward part of the ship, could not afterwards be closed. Many compartments must, therefore, have been flooded in addition to those which were actually breached by the collision.

(*c*.) That the sea rushing into these compartments gradually depressed the bow of the ship from its normal position (about 10 feet above water) to 13 feet below water, or a total depression of about 23 feet, while the stern rose about 6 to 7 feet. Thus the forward half of the vessel was almost completely submerged. This extreme change of trim produced a great diminution of her stability.

(*d*.) During the same time the heel to starboard (the wounded side) very slowly increased until a transverse inclination of 18 to 20 degrees was attained before the lurch began.

4. This comparatively slow but continuous change of position can only have been caused by the gradual flooding of compartments adjacent to or in communication with the compartments breached by the collision.

There are many compartments forward respecting which the evidence does not clearly show whether or not they were closed before the collision. But if only those which the testimony of witnesses shows to have been certainly flooded are taken into account, the result is a loss of buoyancy sufficient to produce the change of trim and angle of heel observed before the lurch began.

5. The great weight of water thus gradually admitted into the forward part of the ship might eventually have caused the ship to founder by the head. The reason why she capsized before foundering has now to be explained.

6. The armor door on the starboard side at the forward end of the battery, the 6-inch gun ports of that battery, and the turret ports were open at the time of the collision, and were not subsequently closed. Observers on other ships noted that the water had reached such a height as to permit its entry through the open turret ports and armor door; also that the ports at the forward end of the battery on the starboard side were awash at the moment when the lurch commenced.

7. The consequent inrush of water into the battery, accompanied by the descent of large quantities of water from the upper deck within the battery through open hatchways into the lower portions of the ship and the inflow of water through the turret ports, necessarily had the effect of suddenly destroying the ship's stability, already very seriously reduced by the submergence of the bow, and of making her capsize.

8. The capsizing of the *Victoria* under the special circumstances above described does not suggest any insufficiency of stability in the design of that vessel. The provision made was ample for all requirements. When fully laden and in seagoing trim the metacentric height was 5 feet, stability reached its maximum at an angle of $34\frac{1}{2}$ degrees to the vertical, and the range of stability was $67\frac{1}{2}$ degrees.

9. The question remains, what would probably have happened if all doors, hatches, &c., had been closed in the *Victoria* before the collision took place. Investigation shows that while the loss of buoyancy must in that case have been considerable, yet, making all due allowance for probable damage, the ship would have remained afloat and under control and able to make port under her own steam. Her bow would have been depressed about to the water level; her heel to starboard would have been about one half of that observed before the lurch began; her battery ports would have been several feet above water, and she would have retained ample stability.

10. The detailed evidence establishes the fact that watertight doors, hatches, &c., in the *Victoria*, were in good order. It contains nothing which suggests a doubt of the efficiency of the system of watertight subdivision existing in the *Victoria*. At the parts affected by the collision the subdivision was minute, but doors were left open. According to the established practice of the Admiralty in all classes of ships, the number of watertight doors is made as small as possible consistently with the essential conditions for working and fighting the ship.

11. The evidence clearly shows that the existence of longitudinal watertight bulkheads in the *Victoria* was not the cause of her capsizing. There were only a few minor longitudi-

nal partitions in the fore part of the ship. Many of these were inoperative because of damage or open doors.

12. It also proves that the loss of the ship was not due to injuries sustained above the protective deck. Those injuries produced a loss of buoyancy forward which was unimportant compared with that resulting from the flooding of compartments below the protective deck.

13. The fact that the *Victoria* was not armor belted to the bow had no influence upon the final result of the collision. No armor belt could have prevented the ripping open of the bottom below water by the ram bow of the *Camperdown* and the flooding of the compartments to which water could find access through the breach.

14. In conclusion, their Lordships are of opinion that the general structural arrangements of the *Victoria* (similar in many respects to those of other ships in Her Majesty's navy), with the arrangements of watertight doors, armored belt, and protective deck, did not by any fault of principle contribute to the loss of the ship; but that, on the contrary, had the watertight doors, hatches, and ports been closed, the ship would have been saved, notwithstanding the crushing blow which she received from the *Camperdown*.

15. The duty remains of taking every possible step to prevent the recurrence, under similar circumstances, of the conditions which, after the collision, resulted in the loss of the ship.

Regulations will therefore be issued to the fleet which, while maintaining the responsibility and discretionary powers of commanding officers, will insure that, under special circumstances, and particularly when there is risk of collision, doors, hatches, &c., shall be kept closed as far as possible and men stationed at any that are necessarily left open.

These regulations will also direct that, under certain conditions arising out of collision or under water attack, the gun ports and other openings in the upper structure shall be closed before water can enter and endanger the stability of the ship.

ADMIRALTY, October 30, 1893.

CAPTAIN BOURKE'S TESTIMONY.

The following part of Captain Bourke's testimony brings out some points which may be of interest.

There is no direct evidence that the hatch leading from the turret escape, up which the men whose station it was to close the doors abaft H, was closed. After coming up the turret escape there is evidence that the hatch was closed, because one man was shut in, and, as he describes, he thought he was done for, but the hatch was opened again and he escaped. But there is no one saved who can say whether that escape hatch was shut a second time, but it would seem probable that it was so, as it was quite certain that it must have been in the men's minds that it was necessary to shut it, having already done so once, but I can produce no evidence that it actually was closed. I could only say that it had been closed once, and, I suppose, the people who closed it suddenly remembered that there was one of them not up, opened the hatch and let him out. The door at the fore end of the main passage was closed. With reference to questions which were put, arising from the fact that the helm jammed after the collision, there is no evidence to show whether water actually entered the hydraulic room or not, but I should like to explain to the Court the lead of the exhaust steam pipe which was in communication with the hydraulic engine on the starboard side. The exhaust steam pipe for the starboard hydraulic engine was, I believe, an 8-inch pipe. It started from the auxiliary condenser aft, went along the tops of the boilers, then dipped down to the starboard hydraulic room. From there it went forward, and I think I am right when I say in the submerged torpedo flat it branched, and the same exhaust steam pipe was used for the capstan engine. There was no valve between the exhaust steam pipe for the capstan engine and the hydraulic engine. Therefore, if by the shock of the collision that exhaust steam pipe was broken, there was free communication for the water to run back through that exhaust steam pipe to the lower level and so stop the hydraulic engine. But that would not fill the hydraulic compartment, it would only stop the engine. There is further evidence, I think, that probably this engine must have

been stopped, as although there is every reason to believe that the valves were open to admit pressure to the hydraulic boat hoist, the pressure never got there. The port ejector tank was where the stoker double-bottom party had been employed. None of these men were saved. The ejector tanks, as were all other such compartments, were always closed at sea, and, as I have before stated, I can only suppose that if the stoker double-bottom party were not at work there, this hatch would have been closed. If they had been at work there, they had plenty of time to leave their work and close the hatch after them. It was a small hatch about 2 feet square.

As the ship settled down the water undoubtedly entered through the turret ports which they had not time to close. The water ran into the turret, then filled up the well underneath the 100-ton guns, and from there ran out through the door on either side of the turret and filled up the redoubt. From there its only escape would be either through the small louvres of the ventilating system of the ship and down, or through the turret escape hatch into the flat below. The turret escape hatch shut from up down, so that the pressure of water on top would tend to shut the hatch and not to open it. The water could also find its way down through the ammunition hoists to the magazine. I would add that though the ports of the turret were not shipped, if the water rose to the top of the turret there was absolutely nothing to prevent it from pouring down through the gratings on top of the turret guns. There were no means of making that water tight except by a canvas cover.

Is the ammunition hoist a water-tight compartment, where it passes through the flat between the redoubt and the magazine? Yes.

Were there any large ventilating trunks passing below the protective deck from the submarine mining flat aft? Yes, there was a delivery from the ventilating trunk in the submarine mining flat.

Who will be able to tell us more accurately what the lead of those large trunks was? I think Mr. Rawlingson, the engineer, could give you a clearer account of it than I could, as I am not quite certain.

Mr. Rawlingson was then called and questioned as follows by the Court:

Can you say what the two small water-tight scuttles marked in the plan abaft the turret support, one being in the air-compressing room and the other in the well room on the starboard side, were? No; I cannot say. I do not remember seeing them at all.

The two following questions were asked on cross examination by Captain Bourke:

Is it possible that the two places shown as hatches on the Admiralty drawing referred to in the last question could be what is marked in other plans as "escape from hydraulic room," and was it the trunk to which an exhaust fan was fitted to pump the hot air out of the hydraulic room up into the funnel casing? The witness, having referred to the plans, said: The escape for the hot air from the hydraulic engine room by means of an exhaust fan is in the same position as the watertight scuttles shown on the Admiralty drawing.

Then you are of opinion that the scuttles shown on the Admiralty drawing are actually the trunks over the hatch, or those passing from the hydraulic room to the funnel casing? Yes.

CAPTAIN BOURKE'S DEFENCE.

MALTA, *27th July, 1893*.

Gentlemen: In placing before you the defence of the surviving officers and men on their trial for the loss of H.M. ship *Victoria*, I would first express to you and to the service in general with what true and sincere feelings we one and all tender our thanks for the very great sympathy and kindness which has been shown to us on all sides. Everyone seems to have striven to lighten our sorrow and help us in our distress, and I seize this, perhaps the only public way open to me, of expressing the sentiments of us all. I can only add that none of us will ever forget it.

2. I now pass to the question of the time shortly preceding the accident. The evidence, I think, is clear on the subject, and, with some slight additions made by Staff Commander Hawkins-

Smith and Flag Lieutenant Lord Gillford, is much the same as in the statement first forwarded. In my original statement I represented the Staff Commander to have said to the Admiral that eight cables would be better than six. In Staff Commander Hawkins-Smith's evidence he states he said that to perform that manœuvre the distance should be at least eight cables.

I wrote the report and gave it as my impression that the words used by the Staff Commander were exact, but I am glad he has had an opportunity of correcting any statements made by me which may have given the Court an erroneous impression.

3. I must now pass to the most painful part of my evidence, and I am sure the Court will understand the hesitation on my part as to stating what actually took place between the late Commander-in-Chief and myself. I can only say that I have represented to the Court to the best of my recollection what actually did pass. The interview was very short, and I followed the Flag Lieutenant on deck almost immediately. Then comes the question with what impressions I left the late Commander-in-Chief's cabin concerning the manœuvre in question.

4. I may say that in manœuvres of any sort the Commander-in-Chief, except to discuss as to the actual position of anchoring, never consulted any one as to the manœuvres he intended to carry out. I even think that the Flag Lieutenant very seldom knew any intention of the Admiral until the moment of the signal. I do not say this to lead the Court to suppose that I for an instant think I ought to have been consulted. On the contrary, there was no more reason for consulting me as to manœuvres than any other captain in the squadron. The Commander-in-Chief was always ready and glad to discuss any manœuvre after it had been performed, but I never knew him to consult any one before.

5. So it comes to my impressions. I must say that I think any impressions I did have arose from my absolute faith and confidence in the Commander-in-Chief, and my idea is that I left that cabin not understanding what was going to happen or how it was to be done. I would add, I think that no one ever criticised the Commander-in-Chief as to what he intended to do. I

do not know to what extent I may go, but I do not seem to think that open criticism to one's superior is quite consonant with true discipline. Representations may be made and suggestions put forward which may show to the superior officer the points on which these suggestions or representations are based, but to acknowledge an open criticism to an order as necessary from subordinates is to set out on a dangerous course, striking deep at the foundation of discipline and responsibility.

6. Sir George Tryon had a master mind. He loved argument, but was a strict disciplinarian. He always used to say he hated people who agreed with him, but that again was different from arguing against a direct order. With this and the fact that I was serving under an Admiral whose experience was far-reaching and whose vast knowledge of the subject of manœuvre was admitted by all, I seem to have left his cabin not clear in my mind what was to happen, but confident somehow that the Commander-in-Chief himself must be clear as to his intentions.

7. I think at this point I should introduce a subject which has come out in evidence. It was rather inferred by two witnesses that certain doubts had arisen in their minds before as to manœuvres carried out by Sir George Tryon. When I say doubt I may perhaps put it too strongly, but my impression was that the witnesses said they were not clear in their minds on the occasions referred to. In justice to the late Commander-in-Chief I asked what these were. In one case the Court was told that one division was sent three miles ahead and then ordered to alter course 16 points and return. This was off Boudroum, in the eastern entrance to the Kos Channel. I submit this could hardly be classified as a manœuvring signal, though, of course, the Second Division could not tell why they were sent the three miles ahead. But it must shortly have been evident when the First Division's movements and turns were observed. The Second Division had been not manœuvred, but detached, to perform a specific duty, and it was not necessary or convenient, under the circumstances, to convey to them the projected movements of the First Division. They were detached to represent an enemy attacking in line ahead.

8. I now pass to the moment of the hoisting of the signal which directed the columns to turn inwards.

First, as regards that signal:

I submit it was the right and proper signal to hoist when directing the two columns to turn inwards 16 points in succession. I also submit that the fact of the Second Division signal being hoisted superior to the First Division signal has no bearing on the case. The signal to the second Division was a specific signal to that division, and that division only, and it mattered not one iota where it was hoisted. Further, I submit that there was only one meaning to the signal as it was flying and seen by the remainder of the squadron, and that that meaning was neither more nor less than that the Second Division was to alter course 16 points to starboard in succession, preserving the order of the fleet, and the First Division to alter course in succession 16 points to port, preserving the order of the fleet.

The Commander-in-Chief gave the order for this signal to be bent on while he was on the after bridge. He then came forward on to the top of the chart house where I was and also the Staff Commander, the Officer of the Watch, Mr. Lanyon, Midshipman, and J. Baggett, Yeoman of Signals.

9. When going to an anchorage or when manœuvring without signals the Commander-in-Chief always came forward to the fore bridge or chart house. When going to an anchorage with the squadron I took all my orders from the Commander-in-Chief as to easing engines and stopping the ship, informing him when we were respectively 1 mile, 4 cables, and 2 cables from the anchorage.

When manœuvring without signals the Commander-in-Chief gave me all the directions as to the movement of the helm. On all occasions of manœuvring by the General Signal Book or the Manœuvring Signal Book the Commander in-Chief was aft.

It used to be a common saying with him that the Admiral's eyes should be aft and the Captain's eyes forward.

10. When the signal directing this manœuvre was hoisted the *Camperdown* did not hoist her signal close up. The Admiral then asked who she was waiting for, and the Flag Lieutenant

went aft a little to see if she was waiting for any ship in the First Division to answer.

While the Flag Lieutenant was aft the Commander-in-Chief ordered the *Camperdown's* pendants to be shown and a semaphore to be made to her "What are you waiting for?"

When the signal was hauled down the Commander-in-Chief made the remark, "Go on." The Staff Commander actually gave the orders for the helm.

It was very soon after this that I said to the Admiral words to the effect that "We had better do something; we shall be too close to that ship."

Then I told Mr. Lanyon, Midshipman, to take the distance of the *Camperdown*. I remember being impatient with him, and he eventually, I think, said, "3¼ cables;" but I remember at the time thinking the distance was underestimated. It was then I asked the Admiral's permission to reverse the port screw, which request I repeated two or three times, I think. At last he said "Yes," and the port telegraph was immediately reversed, and shortly after I reversed the starboard telegraph.

The order for closing water-tight doors was given about one minute before the collision.

11. I stated in my evidence that I did not think the "way" of the ship had been appreciably diminished. I should like to say that by that I meant that actually, from the moment of turning astern with both engines to the time of the collision, the speed during that time was not materially diminished. Undoubtedly, putting the helm hard over and after that reversing one screw did check the ship's "way," and I estimate that at the moment of the collision the *Victoria's* speed must have been about 6 knots or perhaps less.

12. A question was asked whether any orders existed in the fleet to the effect that inner screws at manœuvres were not to be backed, or, more generally speaking, that ships were not to "jockey" with their screws. There were no such orders from the Commander-in-Chief, but under ordinary circumstances of manœuvre I was aware that he did not like the practice.

The question which now presents itself is whether with the

Admiral beside me on the chart house, he being in full view of the manœuvre, I should have acted as to reversing the screw or doing something without reference to him.

This question can only be answered by the Court, and in leaving the decision in their hands I have two points to lay before them :

1st. That the Commander-in-Chief was there and on the chart house absolutely beside me, and, in a certain degree, conducting the manœuvre of the *Victoria*.

2d. That whenever he had been forward before, it had been his custom, going to an anchorage with a squadron, to himself give directions about the engines.

I do not for a moment wish the Court to suppose that I am anxious to throw off any of the responsibility which, under all circumstances, rests with the captain of a ship. I have only to lay before the Court that my position at the moment the manœuvre commenced was one which I fancy very few, if any, have ever experienced in the service, especially in the presence of a master mind such as that of the late Commander-in-Chief.

A question was asked as to what I should have done had the Admiral been at his usual post during manœuvres, namely, on the after bridge. To that I must honestly say, "I don't quite know." But my feeling is that I should have taken more strenuous action at an early period of the manœuvre, and without the sanction of the Commander-in-Chief, and I think I should have sent aft to inform him of what I had done.

13. Many questions have been asked as to the fact of the Commander-in-Chief hailing the *Camperdown* to "go astern." I seem to be sure that this hailing took place after the collision. I do not think it was before, at least I never heard it, and I did hear it afterwards.

14. I wish now to refer to the signal from the *Camperdown*— "Did not quite understand your signal." Evidence given by eye witnesses on board the *Victoria* would seem to point to the fact that for some reason, probably the rapidly changing relative bearing of the two ships, this signal was not taken in or reported on board *Victoria* before the collision. I was close to the Com-

mander-in-Chief the whole time, and I must say I never heard it reported.

It is in evidence that I E was hoisted by the *Camperdown* just as the turn began, and it seems possible, as I before stated, owing to the constantly varying relative bearings, that the signal was not properly taken in until the last or nearly the last moment. The evidence on this point is, I submit, most conflicting. What seems clear is that the *Camperdown* hoisted I E as the turn began.

15. I now pass to the moment of collision. The evidence of most witnesses seems to show that the *Camperdown* struck rather from aft than from forward. The Staff Commander of the *Victoria* states that the *Victoria's* head had almost touched W.N.W., and the Navigating Officer of the *Camperdown* says that the *Camperdown's* head was S.W. by S. This would give the angle of impact as one point abaft the beam. This is strong evidence. I, of course, only judged it by eye, but I must confess that it struck me at the moment that the angle of impact was more as I stated it. Perhaps I might modify that statement. The angle of impact may have been at right angles to the curve of the ship's side, but it did not look to me as abaft the beam. This impression seems to be borne out by the written statement placed in Court by the Chief Constructor concerning the damage to the bow of the *Camperdown*.

16. What I saw of the collision was the *Camperdown's* stem crushing in the upper deck about 10 or 11 feet, the upper deck being ploughed up and the wooden deck splintered in every direction.

The sterns of the *Victoria* and *Camperdown* swung slightly together. The *Camperdown* backed out clear, I suppose, not more than a minute from the moment of striking the *Victoria*, and at an angle of 20° abaft the beam.

17. It was at this moment I said to the Commander-in-Chief, "I think I had better go below to see about the doors," and he said, "You go below to look after the doors; I will attend to the engines." When I left the deck the engines were stopped. I then went below, as described in my first report.

18. When I was in the flat on the main deck, before M bulkhead and abaft the angle bulkhead on the starboard side, there was certainly an order passed down for everyone to go on deck, but I have entirely failed to discover who gave that order. I certainly heard it myself when I was in the flat, and I do not think it emanated from anyone below in the flats. I state this so as to dispel any idea that the men were in a panic below. They went up the ladder in a quiet and orderly manner.

I am convinced that all side scuttles were properly closed in the after flats. Only two marine ward-room servants were saved, but I feel almost certain that they all carried out their duties, namely, to close those scuttles. I had never heard of any omissions under this head when exercising closing water-tight doors. I can call evidence as to the scuttles in the Secretary's cabin and Commander-in-Chief's office, which, perhaps, might be considered doubtful as to whether open or closed. I may say they were closed properly.

19. When I came up from below and passed through the flat abaft M bulkhead, which must have been a minute or less before the ship gave the lurch to starboard, I can only say that there was no water in that flat, neither did I hear the sound of water rushing in. There were no scuttles in the flat before M bulkhead.

20. I wish, again, to refer to my interview with the Fleet Engineer, after I had left the engine room and met him about half way along the main passage. The electric lights in the main passage were burning very dim, and I even ran into the Fleet Engineer before I saw him. I feel sure when he said to me that "all was tight, as far as he could make out, abaft the foremost boiler room," that he meant the fore end of the foremost boiler room. I cannot think that the water could have entered that boiler room without his being aware of it. If, by any chance, the horizontal door close to No. 5 bunker, leading into the sloping shoot, had been closed when water-tight doors were closed, no water could have reached No. 7 bunker, and even if No. 7 bunker had filled with water there was the door leading into the stokehold that could be shut in a moment. Therefore, I am

strongly of opinion that the water never penetrated into the fore boiler rooms. Neither do I think it penetrated into the hydraulic rooms, which were before the boiler room; but I do think that my theory concerning the stopping of the starboard hydraulic engine, and consequent jambing of the helm and failure of the hydraulic boat hoist, is the correct one, namely, that the water flowed back through the probably damaged exhaust steam pipe in the capstan-engine flat. I do not propose to refer any more to a long statement made by me concerning the amount of water which I supposed entered the ship, but in estimating it I did not very closely consider or make any particular statement respecting the terrible wrecking of compartments, decks and bulkheads that must have taken place forward when the blow was delivered. No one can imagine the feeling at the moment of collision. It was not a shock, nor was it a blow, but we felt the ship being carried bodily sideways, and by one witness this was estimated as a ship's breadth, 70 feet.

Also, a statement is made by Commander Jellicoe, who was sick at the time and in bed in his cabin aft, which shows the power of the blow. He states that, at the moment of the collision, the foremost bulkhead of his cabin seemed to be momentarily wrenched, and looked as if it was going through the ship's side. If this wrenching strain went on aft, what a terrible effect it must have had forward.

21. With regard to the question of efficacy of the automatic air valves in the ship. During the late winter months, when the *Victoria* was in dockyard hands, I ordered that the closest attention was to be directed to all the air valves, and I frequently asked questions about them, and I feel pretty certain that every one of them was overhauled thoroughly by the dockyard. They were not tested after the ship recommissioned. The ship left dock on the 8th of May, and we left for the summer cruise on the 27th of May.

22. Evidence at great length, concerning which water-tight doors were open and which closed, has been placed before the Court in statements supported by witnesses, and I have nothing further to add than that my firm belief is that all hatches and

doors, not used as gangway hatches and doors, were closed before the collision, in accordance with the orders of the ship when at sea. Direct evidence seems to show that all doors and hatches between E 2 bulkhead and the main passage door on K bulkhead, inclusive, below the upper deck, were closed before or after the collision, except the sliding door in H bulkhead, the door leading to the small air-compressing compartment before K bulkhead the port side, and probably the horizontal door in the armored deck leading to the sloping coal shoot, and the door of No. 5 bunker.

No direct evidence shows that the hatch of the port-ejector tank was closed, but I think I have produced strong presumptive evidence that it must have been so.

I may add, that closing water-tight doors, placing collision mat and general collision stations, had been frequently exercised from the time the ship was commissioned.

23. A question was asked me by the Court—Why the order to close water-tight doors was given so late as one minute before the collision? My answer was—It was given when it was seen the collision was imminent. I can only refer back to a former sentence in my defence, where I stated that my position was one which I fancy very few, if any, have ever experienced in the service. It did not strike me as necessary to close the doors when the signal was flying or immediately after it was hauled down.

24. I have little more to add now. When I left the main passage and passed through the after flats to come on deck, I saw no one down there. When I got on the upper deck I saw the men fallen in on the port side. I went up the after bridge ladder, and there I found officers and men in their stations for hoisting out boats.

I saw Commander Jellicoe, although on the sick list, on the port side of the bridge, with the flags in his hands for the signals to the topping lift and purchase of the derrick. I then went along the fore-and-aft bridge with a view to reporting to the Admiral the result of my inquiries below. When I arrived at the foremost cutter's davit the ship gave the lurch described,

and appeared to turn straight over to starboard. My belief is that the heel, when the lurch mentioned took place, was not more than 20°, as I had no difficulty in walking along the fore-and-aft bridge, and had not to hold on to anything. I must say that immediately before the lurch described by so many witnesses I had no idea that the end was so near.

25. I am of opinion that the whole ship's company, officers and men, were on deck, except the poor fellows in the engine rooms and boiler rooms. They were all on the port side of the upper deck, fallen in. When, at last, the men went over the ship's side I cannot help thinking that the majority got outside the ship. Those who were fortunate enough to be washed away from the wreck were, I think, probably all saved, but of those who found themselves immediately over the sinking ship the majority must have been overwhelmed by the terrible agitations of the water, and many, possibly, were struck by the wreckage and loose spars floating up.

26. The opinions are conflicting as to whether any explosion of boilers took place. In my first statement I mentioned an explosion, but I might well have mistaken the agitation of the water for the explosion of the boilers. I certainly heard or felt no explosion in the water, and I can hear of no one now who can say he felt the water hot.

There is no doubt that amongst the stokers and marines there were many who could not swim, or who were indifferent swimmers. In those cases I am afraid they had a very bad chance.

It should be noted, I think, that of those saved the position in which they were in the ship when she capsized seems to have made no appreciable difference. Officers and men were picked up who were in every various part of the upper deck, and no particular place appears to have governed the proportion of those saved.

27. In the course of the inquiry, opinions have been given as to whether the signal "Negative K.Z.," meaning "Negative send boats," contributed in any way to the great loss of life. In my opinion, one which I may say is shared by all the surviving officers of H.M. ship *Victoria*, this signal made no difference in

the amount of people drowned. It must be remembered that this signal was made when, immediately after the collision, the Flag Lieutenant reported that the *Dreadnought* was lowering her boats. It is clear that the Commander-in-Chief had in his mind the possibility of reaching shallow water, and actually turned the ship towards the shore. The Staff Commander states the speed had perhaps reached two to three knots.

It would have been very inconvenient for the ships to have followed the *Victoria* with their boats in the water. Further, I think it was very fortunate that the boats of the squadron were not all clustered round the *Victoria*. I am strongly of opinion that if this had been the case many of the boats might have received severe damage from wreckage, and in some cases endangered up to a point of being capsized by the agitations of the water.

It must not be forgotten that a semaphore was made, "keep boats in readiness, but do not send them."

Those who experienced the terrible agitation of waters consider that it was to this that the great loss of life must be attributed. Vast quantities of spars and wreckage shot to the surface, wounding many, but to the great upheaval of water I attribute the serious loss of life. I am further of opinion that no boat could have worked effectually immediately in the vicinity of this terrible swirl.

28. At this point, having I trust touched upon all the important facts brought out in evidence, I shall refer to the order and discipline by which all were influenced in the short but terrible time between the ramming of the *Victoria* and her capsizing.

When the crushing blow delivered by the ram of the *Camperdown* was felt, the impression which passed through everyone's mind must have been one of serious apprehension. No one in the ship, knowing what had happened, could have failed to appreciate that the conditions were certainly serious. With this in view, I should like to lay before the Court a few remarks on what I submit was the discipline and self-control which was exhibited by all. There was absolutely no panic, no shouting, no rushing aimlessly about.

Officers went quietly to their stations, and everything was prepared, and the men were all in their positions for hoisting out boats or performing any duty that they may have been ordered to carry out. The men on the forecastle worked with a will until the water was up to their waists, and it was only when they were ordered aft that they left their work to fall in on the upper deck with the remainder of the ship's company.

In the case of the men working below, I was a witness to their coolness. When the order was passed down for everyone to go on deck, there was no haste or hurry to desert the flat. I can further testify to the men below in the engine room. In the starboard one, all were in their stations, the engineer officer was there, the artificer, and the stokers. I am sure that those in the port engine room and the boiler rooms were equally true to themselves, to the country they were serving, and to the trust that was reposed in them.

In all the details of this terrible accident one spot especially stands out, and that is the heroic conduct of those who, to the end, remained below stolidly, yet boldly, at their place of duty. All honor to them especially!

The men fallen in on the upper deck also showed the same spirit. I would recall to you what I described in my evidence. When the men were turned about to face the ship's side, it must have passed through the minds of many that to "look out for oneself" would be the best thing to do. The men must have seen the others coming from forward wet, which in itself might have increased their apprehensions. This order to turn about was given apparently about a minute before the end, and I can hear of not one single instance of any man rushing to the side. It only wanted two or three to start a panic, but I think it should be on record that not one was found who had not that control over himself which characterizes true discipline and order. It has been shown in evidence that no one jumped from the ship until just as she gave the lurch, which ended in her capsizing.

29. I imagine there is not a single survivor who can give any clearer reason for his being saved than that he was more fortunate than his neighbors.

There is one deeply sad circumstance connected with the accident, and that is the very large proportion of midshipmen who lost their lives. These young officers at the commencement of their career were thus cut off; but it will be to their undying honor that, young as they were, they also showed that spirit of trust and bravery, and one and all remained at their posts on deck to the end.

30. There is no doubt that among those lost many individual acts of heroism and disregard of self must have been displayed, but I regret I am only in a position to state one. This is the case of the Reverend Samuel Morris, Chaplain of H.M. ship *Victoria*, than whom no one in the ship was more beloved or respected. It is his words—"Steady, men, Steady"—when the end came, which bring before one the appreciation of his coolness and valor.

Even at the moment of the ship capsizing we only hear of him careless of his own safety, exhorting the men to be cool and calm.

In his daily life on board he mixed with the men, knew all their thoughts and advised them in their troubles. A noble character like this inculcates by his example the discipline and obedience which was shown on board the *Victoria*.

31. Amongst those saved equal acts of bravery and coolness were displayed. It has been my privilege to forward some names to the Commander-in-Chief, for the part they took in saving life.

32. I have now to conclude my statement by expressing my own deep grief and that of the survivors of H.M. ship *Victoria* for the terrible loss we have sustained in the death of the late Commander-in-Chief and so many of the officers and crew of our ship. It is a feeling deep and sincere which must ever remain in the hearts of us all. For myself, I cannot pretend to describe the overwhelming loss which I have experienced in the death of my Chief and my kindest friend. He was always ready to help and advise, there was never anyone in trouble whose cause he would not identify himself with.

It is not necessary for me to praise him as an officer. Everyone who knew him, aye, and many others, acknowledged his worth. It adds doubly to my sorrow when I know that the service has lost one of its best and most capable leaders.

MAURICE A. BOURKE, *Captain*.

THE INJURY TO THE *CAMPERDOWN*.

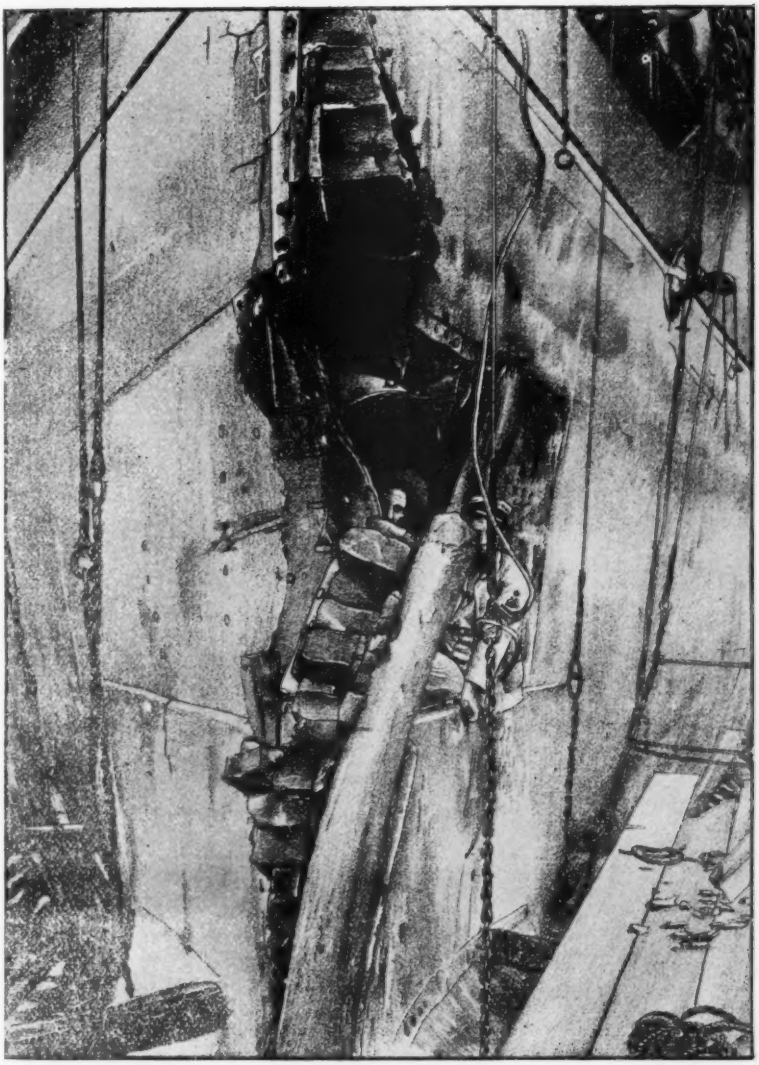
Mr. White's report necessarily contains very little information on the injury sustained by the *Camperdown*, but the minutes of the proceedings of the court martial at Malta contains much that is of interest, besides the illustrations, which are here reproduced. The following letter of the Chief Constructor of Malta dockyard is the one referred to by Mr. White on page —, and was submitted to the Court, together with a model of the *Victoria*, to facilitate an understanding of the injury received by that vessel:

MALTA YARD, *26th July, 1893*.

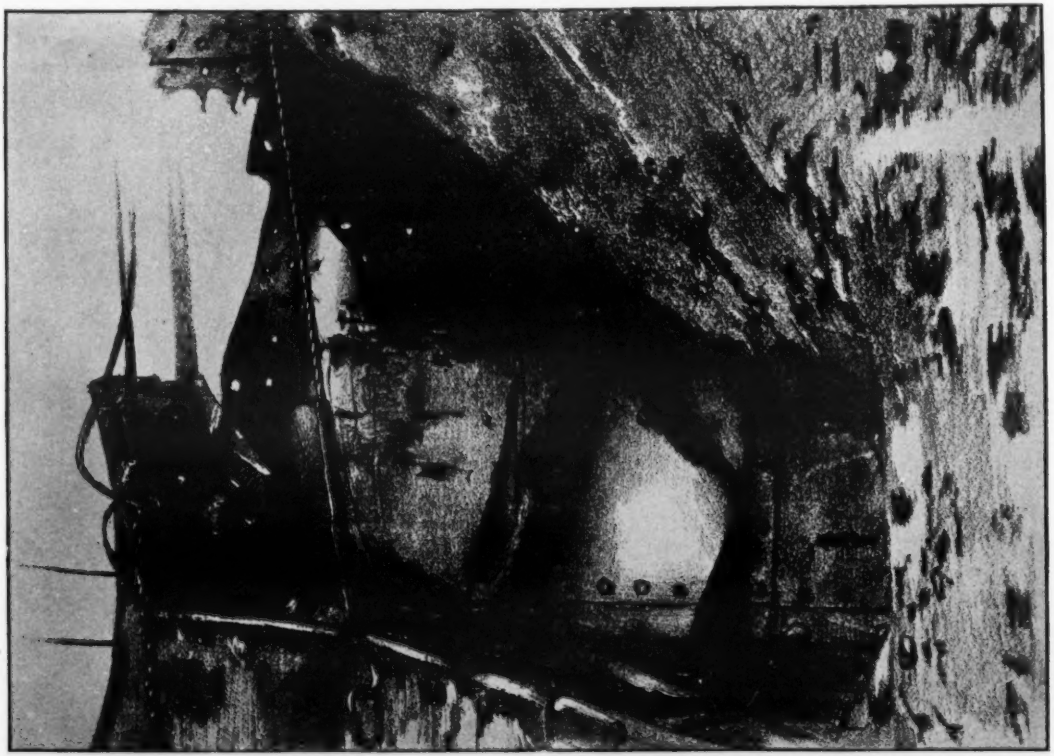
In estimating the damage done to the bow of the *Victoria* from the collision with the *Camperdown*, I have formed my opinion entirely from the results of the collision shown on the stem and bow of the latter ship. On examination in dock I found that the stem was broken off abruptly at about the height corresponding with the armor deck of the *Victoria*, the part of stem below the fracture being driven over to port about 18 inches, and bent in a fair curve which commenced about 20 inches above the prow support at armor deck. The bow plating on the port side was sheared off along the upper edge of the 2-inch strengthening plate to ram, and doubled completely round inboard to a distance of 15 feet 3 inches aft from the extreme fore end of ram, extending a short distance above the fracture of the stem. Above this, to the upper part of the stem, the bow plating on the port side was driven considerably over to port, and showed unmistakable signs of the upper piece of stem above the fracture having been forced over towards the port side. On examining the fracture of stem I found an indentation on the starboard side of the fracture, apparently where the *Victoria's* armor deck first came in contact with the stem of *Camperdown*. At the same height the

starboard plating, where it ends on the stem, had received a severe blow, and was driven over to port, at this point only showing a deep indentation and fracturing the plate at a rivet hole. These results confirm my opinion, that the force of the blow was delivered in a slightly oblique direction from the normal to the curve of the *Victoria's* bow, by the starboard angle of the front of the *Camperdown's* stem. The starboard plating is scarcely injured beyond the fractures, and in some of the rivet holes where the stem was forced away from it. The two ships were approaching each other under opposite helms, *Victoria* under starboard and *Camperdown* under port helm, the shock would, therefore, considerably increase the turning movement of both ships, and would rapidly alter the angle at which they first collided, tending to bring their sterns towards each other, freeing the starboard bow of *Camperdown* as the stem cut its way in, but forcing the port bow further into the breach made by the stem in the side of *Victoria*. From indications on the gunwale of *Camperdown* and on the port-bow plating it is estimated that the bow of that ship at the upper deck penetrated the *Victoria* about 9 feet. On this assumption I have formed my opinion of the damage done to *Victoria's* bow, &c. For the area of the aperture I have allowed an average of 2 feet beyond the actual section of the bow of the *Camperdown* which penetrated the ship, for the increased damage done to aperture at the side due to the ship's alteration of colliding angles after they struck. With the swinging of the ships, I think it probable that the bulkhead of starboard chain locker was injured and displaced, and that it is possible the bulkhead of the capstan engine flat was forced, Nos. 22 and 23 transverse bulkheads being driven in when the ships struck. From this it will be seen that the ship's side was opened up from the gunwale to within a short distance of the water tight flat lately fitted in the ship.

As the order for closing water-tight doors does not appear to have been given until a very short time before the collision took place, it would seem probable that very few of the doors or scuttles could have been properly secured before the men, whose duty it was to close them, were driven back by the inflow of



BOW OF "CAMPERDOWN."



BOW OF "CAMPERDOWN"—STARBOARD SIDE.

water. I have assumed that below the main deck the watertight doors and scuttles between the collision bulkhead and station (31) were all open, except those in the Port Reserve bunkers, and that in bulkhead of submerged torpedo room. My statement shows the total capacity of each compartment to contain sea water, and the amount I consider could have entered each, taking into consideration the probable displacement of the various stores, &c., in each compartment. It would appear from this, that the capacity of the open compartments to receive sea water would be about 900 tons, which I consider would be sufficient to immerse the ship 1 foot 8 inches deeper in the water, and alter trim at least about 13 or 14 feet, which would give a depression of the bow of about 9½ feet, and an elevation of the stern of about 4 feet 6 inches from original draught; this would bring the upper deck about level with the water, and allow the whole mess deck to fill. The effective buoyancy of the fore part of the ship would be so greatly reduced by the opening up of so large a portion of the interior to the sea, and reducing the area of the plane of flotation, that the conditions on which the ship floated would have been entirely altered, the longitudinal stability of ship would have quite vanished, and consequently a very slight force would capsize her. The foundering under the circumstances, was inevitable; but the time she remained above water was considerably shortened by forcing the ship ahead as she settled down. The area of the aperture in the *Victoria's* side below the water line, would be about 132 square feet, and I compute that about 90 tons of water per second would flow into the ship had the interior been free from any obstructions to its progress; but taking into consideration the number of compartments, and the various bulkheads, flats, &c., which would obstruct its free flow, I am of opinion that about two minutes would be sufficient time for the inflow of enough water to immerse the ship nearly 2 feet deeper, and alter her trim at least between 13 and 14 feet. Say, depress the bow 9 feet 6 inches, and elevate the stern 4 feet 6 inches, which would submerge the fore part of the upper deck, and allow the whole mess deck to fill.

JOSEPH NEWNHAM,
Chief Constructor.

In making his first official report on the collision (June 22, 1893), Rear Admiral Markham stated the condition of the *Camperdown* to be—

(1.) A jagged hole in the port bow, extending from the stem to an extreme distance of 10 feet abaft, and from 12 to 18 feet below the upper deck, the lower edge being just above the armored deck. It is irregular in shape and the extreme dimensions are 6 feet by 10 feet.

(2.) The stem is broken above the ram, and the upper part turned to port, separating the stem piece and the plating on the starboard side for a depth of 10 feet vertically, commencing at the water line, and attaining a width of 11 inches about 5 feet below, then tapering away to nothing about ten feet below the water line.

The following compartments are full: Carpenter's store room, paint room, fore ballast chamber, boatswain's store room, submarine mining room, tank room, capstan-engine flat, and also the patent fuel space on the port side of the chain lockers.

Subsequently (June 24, 1893), he reported that the fore ballast chamber, the boatswain's store room, the submarine mining room, the tank room, the capstan engine flat, and the patent fuel space had been pumped out and were dry.

From the testimony of Captain Johnstone and Chief Engineer Newton, it appears that there was no water in the patent fuel space, and that the maximum quantity of water in the ship was from 400 to 500 tons, causing a marked change in trim of the ship. The draught of water before the collision was about 27 feet 6 inches forward, and 29 feet 4 inches aft; after the collision it was 32 feet forward and 27 feet 6 inches aft. The Chief Engineer testified that after the collision he opened certain drain valves and sluices, the result being the filling of the fore ballast chamber and the submarine mining room, and the partial filling of the capstan-engine flat. The following entry in the engine-room log will explain what was done:—

Immediately after the collision, went forward to 13.5 magazine flat; found about 3 feet of water on after end of flat; doors of D and F bulkheads open, and also hatches to submarine min-

ing rooms. Closed these and opened drain valves in these compartments to the main drain, when the depth of water decreased. Afterwards went forward and opened valves on B bulkhead, to drain carpenter's and boatswain's store rooms and paint room, and also drain valves of A and B compartments. Put fire engine on main drain, and circulating engine on the bilge, allowing water to pass from main drain to engine room bilges through rack valves, and pumped out magazine flat abaft D bulkhead.

Endeavored to drain carpenter's store room through tank room to port ejector tank, but this could not be done. Closed drain valves. Ran water off cable deck through starboard patent fuel space to starboard ejector tank.

The chief engineer's testimony showed that by opening the drain valves on B bulkhead he admitted the water which then filled the carpenter's and boatswain's store room and the paint room (which were open to the sea), into the fore ballast tank, and that by opening the two drain valves from this compartment he admitted it to the submarine mining room, and that from there it got into the capstan-engine flat, the hatches at the forward part of which lead into the submarine mining room, and had not been closed. He was of opinion that the water which got into the tank room above the protective deck entered through the ventilating pipes, the automatic valves in which must have failed to work. Some water also entered the forward magazines, and the impression prevailed that it could have entered only through the ventilating pipes.

The engine-room log shows that at one time there was as much as 36 inches of water in the engine-room bilges.

Captain Johnstone, in answer to a question by the Court as to how the water was got out of the flooded compartments, stated that the door in the paint room was partially closed by a diver who entered through the hole in the bow, and subsequently that was closed properly, and the doors of the carpenter's and boatswain's store rooms, by a diver going down by the upper deck, a cofferdam having been built from the main to the upper deck round the fore hatchway. When the square of the hatchway was pumped out the horizontal door in the ar-

mored deck was opened and the capstan-engine flat was pumped out.

As stated by Mr. White, there appears to have been some confusion or misunderstanding about the signal for speed astern with the starboard engine of the *Camperdown*, the signal received being for three-quarters speed. The difference between that and full speed, according to the engineer officer of the watch, who was in the starboard engine room at the time, was 13 revolutions, representing a difference in speed of two knots with both engines in operation. The revolutions for three-quarters speed were fixed at 50, and for full speed at 63.

The following comments on Mr. White's report and the Admiralty Minute accompanying it are by Prof. Francis Elgar, and are reprinted from "Nature," December 7 and 14, 1893:

The facts, as far as they are known, are fully, and in our opinion, fairly summarized by Mr. W. H. White, in No. 3 of the Admiralty Minutes, just issued; and Mr. White demonstrates clearly, from the results of calculations made in the Construction Department of the Admiralty, that the movements and behavior of the ship after the accident, and the observed effects upon her line of flotation and her stability, are precisely what would be caused by the entry of water into the compartments at the fore end of the ship, which are known, or believed, to have been filled before she foundered. These calculations serve, therefore, the useful purpose of showing that the water known to have entered those forward compartments that were proved, by evidence given before the court martial, to be filled, was quite sufficient to account for the subsequent capsizing and sinking of the ship, and for the capsizing and sinking to happen exactly in the manner that was observed. This is so, as already stated, whether Mr. White be absolutely right or not with regard to the precise state of each separate compartment after the damage; as the evidence is sufficiently conclusive, upon the whole, respecting the various compartments, to reduce the probability of error to a very small amount, such as would not materially affect the practical results of the demonstration.

The Admiralty calculations thus remove all reasonable doubt

as to whether the compartments known to have been filled were sufficient in themselves to account for the final disaster; and they make it unnecessary, in order to explain what happened, to speculate as to the probability of the collision having been more far-reaching in its effects upon the structure, or internal arrangements, of the ship than the evidence indicates. The evidence, as it stands, is shown to completely account for the facts; and to furnish a solid basis for investigation, or argument, as to the lessons that may now be learned from the loss of the *Victoria*.

1. The effect of longitudinal bulkheads upon the capsizing of the ship.—Mr. White points out that there was no continuous central longitudinal bulkhead in the *Victoria*. In the stokeholds and engine room there were two such bulkheads on opposite sides of, and each several feet from, the center line; but these were far abaft the damaged portion of the hull, and do not appear to have been reached by water that entered the ship up to the moment of sinking. There were a few longitudinal partitions in the fore part of the ship; but some of these were inoperative because of damage or open doors. The effect of filling the compartments formed by these longitudinal partitions has been calculated, and it is stated that this would only cause an inclination of about 5° in the intact condition of the ship. This result does not, however, bear directly upon the actual effect produced in such circumstances as are being considered, because the damage caused by collision not only admitted water into the ship, but it reduced, at the same time, her power to withstand the heeling effect of the excentric compartments that were thereby filled. The ship would only have heeled about 5° with these compartments filled if the hull had been uninjured; but if the hull had been uninjured the compartments would, of course, not have been filled. Mr. White goes on to say: "It appears on investigation that in the damaged condition and at the extreme position which the *Victoria* occupied before the lurch began the flooding of the compartments enumerated and the accumulation of water on the starboard side account for the observed angle of heel, 18 to 20°." This inclination—which is what was really due, in the circumstances, to water being held over to

starboard by the longitudinal partition above referred to; as the accumulation of other water to starboard was merely the consequence of the heeling thus caused—must have allowed the sea to enter the ports and door of the upper deck battery sooner than it otherwise would have done, and thus have hastened the capsizing of the ship. The Admiralty Minute states that "the evidence clearly shows that the existence of longitudinal watertight bulkheads in the *Victoria* was not the cause of her capsizing. There were only a few minor longitudinal partitions in the fore part of the ship. Many of these were inoperative because of damage or open doors."

This conclusion is doubtless correct so far as it relates to the continuous longitudinal central bulkhead, to which the capsizing of the ship was prematurely, though confidently, attributed by certain hasty critics, because such a bulkhead did not exist in the forward part of the ship that was affected by the collision. It clearly does not apply, however, to the minor longitudinal partitions above referred to, because these must have been contributory to the disaster according to the extent by which the water they held over towards one side caused the heel of the ship to increase as the bow became immersed and the stability diminished. It is a question that could only be settled by further investigation, whether the reduction of stability and the heeling effect thus caused was greater or less in this particular case than would have occurred if the water had been free to pass from side to side of the ship within the fore-and-aft limits of the compartments it entered.

2. *What would probably have happened if the doors and ports in the upper-deck battery had been closed.*—Mr. White says: "It is not possible to state absolutely that the *Victoria*, with turret and battery closed, could have been kept afloat permanently under the actual circumstances of the collision;" and he points out that there are many compartments into which water might have found its way eventually, through doors and hatches that were probably open. He considers, however, that "her capsizing would have been improbable even if she had eventually foundered." The Admiralty endorse this opinion in their Minute,

which states: "The great weight of water thus gradually admitted into the forward part of the ship might eventually have caused the ship to founder by the head."

We see no reason to believe that the ship could possibly have been saved by the closing of these doors and ports. By the time the sea had reached them the fore end of the ship was so deeply submerged, and there were so many openings by which water could then find its way into compartments not already filled, that it is difficult to conceive how even the rate at which she was so rapidly sinking could be checked. When the sea had reached the height of the turret ports and the upper-deck battery ports and doors, the ship was inevitably doomed. She might possibly have sunk by the head without capsizing, although this appears improbable. With her stability reduced to the extent described in the Admiralty Minutes, when the bow was under water, and the heel to starboard was great, it would appear that the effect of the increasing quantities of water in the ship would certainly be to capsize her very soon. But whatever might have been the precise manner in which she would have gone down, there appears no doubt that the vessel would have gone to the bottom almost immediately after she did, even if the turret and upper-deck battery ports and doors had been closed.

3. *What would probably have happened if all doors, hatches, &c., had been closed before the collision took place.*—We agree upon this point with the opinion, based upon the calculations of the Construction Department, which is expressed in the Admiralty Minute.

4. *The efficiency of the water-tight doors to the bulkheads, and of the means of closing them quickly.*—This question is one of the greatest importance in the present case, because, as we have seen, the *Victoria* might apparently have been navigated safely into port if all the water-tight doors, hatches, &c., had been closed soon enough to prevent water passing from compartments directly opened up by the collision into others from which they were separated by water-tight bulkheads or decks. The Admiralty expresses strong and unqualified opinions upon this point. Their lordships say "the detailed evidence establishes the fact that

water-tight doors, hatches, &c., in the *Victoria* were in good order. It contains nothing which suggests a doubt of the efficiency of the system of water-tight subdivisions existing in the *Victoria*. At the parts affected by the collision the subdivision was minute, but doors were left open. According to the established practice of the Admiralty in all classes of ships, the number of water-tight doors is made as small as possible consistently with the essential conditions for working and fighting the ship. . . . In conclusion, their lordships are of opinion that . . . the arrangement of water-tight doors . . . did not by any fault of principle contribute to the loss of the ship; but that, on the contrary, had the water-tight doors, hatches and ports[1] been closed, the ship would have been saved." Mr. White says, in his Minute: "No orders were given to close doors until one minute before collision. It is established by the evidence that the doors, &c., were in good order. The failure to close doors, therefore, was due entirely to the insufficiency of the time available, especially in compartments breached by the collision."

The statement that the water-tight doors, hatches, &c., were in good order at the time of the collision appears justified by the evidence; except, perhaps, with regard to the door at the after end of submerged torpedo room, which slides horizontally, and could only be moved six or eight inches when the attempt was made to close it after the collision. Their lordships go on to say that the detailed evidence contains nothing which suggests a doubt of the efficiency of the system of water-tight subdivision. We cannot discover, however, that this question was investigated by the Court Martial. Very complete evidence was obtained as to the exact state of each compartment, and of each opening into the compartments, at the time of the collision; but the general question of the efficiency of the system of water-tight subdivision, which involves that of the water-tight doors and hatches to the various compartments, was not gone into. It would appear, indeed, to have been expressly excluded from the investigations of the Court Martial, since it can only be

[1] It has already been pointed out that the closing of the ports would apparently have had but little effect, and the Admiralty admit that the ship might still have foundered.

judged in relation to the bouyancy and stability of the ship; and the Court confined itself, as stated in the Admiralty Minute, to placing upon the Minutes all evidence obtainable with regard to the closing or otherwise of water-tight doors, &c., but did not feel itself called upon, nor feel competent to express an opinion as to the causes of the capsizing. While it may therefore be true that the evidence contains nothing which suggests a doubt upon these points, it is, on the other hand, equally true that it contains nothing which proves the assertion that the system of water-tight subdivision was efficient.

One of the weak points in the water-tight subdivision appears to have been the doors and hatches to openings in the bulkheads and decks; and especially the impossibility of closing a sufficient number of them after the collision to keep the ship afloat.

The doors upon the mess deck were all closed; but this deck was about three feet above the water line, and there was time to attend to the doors upon it before the inrush of water drove the men away. On the protective deck below, however, and on the platform in the hold, there was not time to get at all the doors and hatches before the water reached them; while most of those that were got at and closed appear to have been only partially and very imperfectly secured. The plans of H.M.S. *Victoria*, appended to the Admiralty Minutes, show ten water-tight doors in the bulkheads on the protective deck, at the fore side of the armor belt. This deck is about 100 feet in length, and includes the whole of the area directly affected by the collision; and there is only one important bulkhead in this space which does not contain a door, viz., that which divides the cable locker from the fresh-water tanks. On the platform in the hold, immediately under the protective deck, there are eight water-tight doors in the bulkheads, while there is in addition a water-tight door in the bulkhead at frame station 35, which forms the after boundary to the space. This was the door which could not be closed when the attempt was made to do it. There is no bulkhead upon this deck in the space referred to which does not contain a door. Besides these doors there are numerous openings, fitted with water-tight hatches, in the decks over the various compartments.

The Admiralty Minute states that the number of water-tight doors was made as small as possible, in accordance with the established practice of the Admiralty. It would be difficult, however, to fit more doors than are shown upon the plans of the two decks that are below the water line in the *Victoria*—the protective deck and the deck below it in the hold.

Judging by the Admiralty plans, it was only a certain number of these water-tight doors that were fitted so as to slide horizontally, and some were merely hinged doors, which could only be closed by entering the compartment in which they were situated, and were secured by a number of clips round the edge of the door. Some of these were upon the most important transverse bulkheads, such as the two bulkheads which inclosed the submarine mining flat on the platform in hold. We have always considered that arrangements should be made for closing all doors in bulkheads that are essential to the efficient water-tight subdivision of the ship from a deck that is at a safe height above water, as well as in the compartments where the doors are; and we believe, also, that this is the Admiralty rule—as it obviously ought to be. If doors are fitted below the water line so as only to be opened or closed in the compartments where they are, they should seldom require to be opened, and never to be left open unless the bulkheads to which they are fitted are not considered essential to the efficiency of the water-tight subdivision. It does not appear by the evidence or by the Admiralty Minutes that a single one of the many doors in the fore part of the ship on and below the protective deck could be closed from a deck at a safe height above water, because the sliding doors cold only be closed, we believe, from the main deck, which does not appear to have been more than three feet above water at the time of the accident, and was almost instantly immersed. In view of these circumstances we cannot agree with the opinion of the Admiralty that there is "nothing which suggests a doubt of the efficiency of the system of water-tight subdivision existing in the *Victoria*." It appears, upon the other hand, quite practicable to improve the efficiency of this system by dispensing with some of the doors and by arranging with reference to the others that every one

which requires to be left open for even an instant, without the certainty of some one being in constant attendance upon it till it is closed, should be capable of being worked from a deck at a safe height above water.

Mr. White says that the failure to close the water-tight doors in the forward part of the *Victoria* has caused suggestions to be made that automatic or self-closing doors should be adopted instead of existing arrangements. This suggestion was, he adds, carefully considered long ago, after certain experimental doors had been tried. He is satisfied that the existing arrangements are the best, and that their safety is only a question of good time being allowed for closing the doors. It must be remembered, however, that when the doors can only be closed in the compartments where they are situated, and these are below the water level, the inrush of water would often effectually prevent the closing of the doors in bulkheads that separate the compartment that is breached from those adjacent to it. Also, with such arrangements below as those of the *Victoria*, it is impossible to insure that an unforeseen accident would always allow of sufficient time to close the water-tight doors in the manner required.

The efficiency of the water-tight hatches, and the chances of their being properly secured in an emergency, when they are fastened by a number of clips round the edge, as at present, is also a question that appears to require consideration; while it is to be observed that the sliding horizontal door in the protective deck of the *Victoria*, which opened into a shoot through which coal was trimmed from the reserve bunkers at after end of protective deck, into the side bunkers in the stokehold, could not be closed from the shoot in which the men worked who were trimming the coal; but had to be worked from the submerged torpedo room, a compartment below the protective deck. This open door had an important effect upon the capsizing, for Mr. White states that "one of the chief causes of inclination to starboard is to be found in the fact that, owing to open doors, water was able to find its way from bunkers above the protective deck, down through the coal shoot, and so to fill No. 7 bunker just before the forward starboard stokehold."

It appears to us that one of the chief lessons taught by the circumstances of this disaster is the necessity of reducing the number of water-tight doors and hatches, and of arranging that all of them which are essential to the efficiency of the water-tight subdivision, and are ever likely to be left without attendance while open, should be capable of being closed, either by a thoroughly satisfactory self-acting arrangement or by appliances for working them from a deck at a safe height above water.

5. The value of an armor belt at the ends for resisting damage.—Their lordships say "the fact that the *Victoria* was not armor-belted to the bow had no influence upon the final result of the collision. No armor-belt could have prevented the ripping open of the bottom below water by the ram bow of the *Camperdown* and the flooding of the compartments to which water could find access through the breach." Mr. White argues strongly against the assertion, which he states has been made, that if a strong armor-belt had existed at the place where the blow was struck the damage might have been greatly reduced and the ship kept afloat. He considers that all the most important compartments which were flooded in the *Victoria* must have been thrown open to the sea under the conditions of the collision, even if there had been such a belt. "The breach in the side might have been different in form and possibly less extensive, especially above water; but it must in any case have been of large extent, and have admitted very large quantities of water in a short time." Mr. White proceeds to argue that the extent to which the *Camperdown* penetrated into the interior of the *Victoria* was not altogether a disadvantage, as the *Camperdown's* bow thus became virtually locked in the protective deck of the *Victoria*, till the relative forward movement of the latter ship was destroyed, and the tearing action of her spur upon the side of the *Victoria* was thereby prevented. "Under the assumed condition of a non-penetrable armor belt, this relative forward movement and tearing action must have taken place." But the Admiralty cannot admit the assumption of impenetrability. Reference is made to cases of collision, such as those between *Vanguard* and *Iron Duke*, and between *Grosser Kurfürst* and *Konig Wilhelm*, which

prove, in Mr. White's opinion, that "the existence of an armor belt is no sufficient safeguard against injuries resulting from serious collision."

The objections that have been made to leaving so much of the ends of some of our first-class battleships unprotected by armor, have been mainly in connection with their defence against gun fire. The gun is, and appears likely for some time to be, the weapon of attack which a battleship must be designed primarily to resist. The attack of the ram can often be evaded by speed or skillful handling; and that of the torpedo by watchfulness, tactical resource and smart conduct on the part of the officers in command. The real defence against rams and torpedoes lies at present much more in the judgment and skill with which a ship can be safeguarded or manœuvred by her officers than in her own intrinsic power of resistance.

At the same time, it is obviously desirable that everything possible should be done to increase the amout of resistance that can be offered by a ship's hull to attack from ram or torpedo. The Admiralty say that an armor belt would have no influence upon the final result of ramming. This statement is based upon two assumptions: (1) that "under a blow of such energy as was delivered on the *Victoria*, the strongest armored side ever constructed must have yielded and been driven in. Its water-tightness and that of the bulkheads, &c., within it adjacent to place where the blow was struck, must have been destroyed, and the ultimate result (as regards the admission of water) would have been practically as serious under the same conditions of open water-tight doors, &c., as that which actually occurred in the *Victoria*"; and (2) that if the *Camperdown's* bow had been prevented by an armor belt from penetrating to so great a depth as was stated into the side of the *Victoria*, her spur would have torn away much more of the bottom plating than it actually did.

The truth of both these assumptions appears very questionable. With regard to the first, it is pointed out that the ram bow of the *Iron Duke* drove the armor of the *Vanguard* bodily inwards more than a foot. The armor of the *Vanguard* was, however, only 6 to 8 inches thick, while the force of the blow

with which she was struck is said to have been two-thirds of that delivered to the *Victoria*. The armor at the point where the *Victoria* was struck would have been 15 or 16 inches thick if she had been fitted with an armor belt, while the energy of the blow delivered to her is stated to have been "about the muzzle energy of a 12-inch 45-ton B.L.R. gun, the estimated perforation of its projectile being about 22½ inches of wrought-iron armor." The armor of the *Victoria* was not, however, of wrought iron, but of iron faced with steel, on the "compound" principle, which offers much greater resistance to penetration than wrought iron.

Seeing that the depth of the armor belt would be 7 to 8 feet, and its thickness 15 or 16 inches, and that the projectile referred to, whose energy is about equal to that of the blow delivered to the *Victoria*, only succeeds in penetrating the plate by concentrating its whole effect upon an area 12 inches in diameter, it does not appear that the armor ought to suffer much from a blow distributed over so much greater an area. The armor of the *Vanguard* was driven in because the supports in its rear were not strong enough to resist the blow. In our present ships the top of the armor belt comes against the edge of a protective deck, which is 2½ or 3 inches thick, and could well be supported and connected to it in such a manner as to effectually resist being driven inwards; and it appears to be mainly a question of fitting a similar bearing at the bottom of the armor, in connection with the armor shelf, to furnish sufficient resistance at the lower edge. Such an arrangement for supporting the armor would not be difficult to devise; and it does not appear impossible to thus construct an armor belt, in a ship like the *Victoria*, that would resist being driven in by such a blow as she received, and would do so without necessarily causing the water-tightness of the bulkheads, &c., adjacent to the place where the blow was struck, to be destroyed by the shock of the collision. The fact is that armor belts have usually been arranged exclusively for keeping out projectiles from guns, and not with the view of resisting ramming. Had the latter been regarded as an important function for armor plating to perform, the lower edge of armor, which would receive the first force of the blow in many cases, would

have been supported in the rear better than it now is, and probably somewhat in the manner indicated.

The second assumption upon which the opinion that an armor belt would have been useless is based is that, by preventing the *Camperdown* from penetrating so far as she did into the interior of the *Victoria*, there would have been serious tearing of the bottom abaft the breach as the ships got clear of each other. In support of this it is stated that the bow of the *König Wilhelm* tore open the bottom of the *Grosser Kurfürst* for some distance abaft the first breach, owing to the speed with which the latter vessel tried to cross ahead of her. This tearing action would depend very much, however, upon whether the point of the ram would have penetrated far enough into the bottom below the armor belt to keep the ships together for a sufficient time, and it is quite likely that it would. Anyhow, it is impossible to say what depth of penetration would be necessary for this purpose, especially as the ram bows of ships by which a British vessel might be attacked, are very different in length and form, and it seems a doubtful process of reasoning which leads to the result that the great depth to which the side of the *Victoria* was penetrated might not have been considerably reduced with advantage.

But the objections that have been made to leaving so great a length at the ends of a battleship without armor are not, as we have said, with reference to their being rammed, but because of the damage to which they are thus exposed by gun fire. The results of the Admiralty calculations show that the effect of gun fire upon the unarmored ends of such ships as the *Victoria* might be very serious. We are informed by Mr. White that the *Victoria*, as she was at the time of the collision, would change her trim 3 feet by the bow in consequence of 110 tons loss of buoyancy above the protective deck. It follows, therefore, that if the whole of the compartments above the protective deck were penetrated so as to admit water, there would be a loss of buoyancy sufficient to change her trim fully 5 feet by the head. The change of trim and extra mean immersion thus caused by the loss of buoyancy would bring the top of the armor belt close to the water line at its fore end; and the slightest inclination

would then be sufficient to immerse the fore end of the armor belt on its inclined side. Perforation of the thin side plating at this point above the armor would thus admit water into the ship over the top of the armor belt and lead to a growing loss of buoyancy and stability, both transverse and longitudinal, which would soon place the vessel in a perilous position. The destruction of such a ship does not thus appear very difficult by the large rapid-firing guns that are carried in cruisers and in the secondary batteries of battleships. These guns, firing twelve to twenty projectiles of 6 inches and 4¾ inches diameter per minute, could be aimed with great precision at the water line of a ship, and would very soon cause the whole of the thin partitions in the unarmored ends to be penetrated through and through, and admit water freely into the whole of the compartments. If the vessel thus attacked were steaming ahead, at the slowest speed possible, the additional water that would thus be forced in would greatly increase the change of trim, and it would only be necessary to follow up the process of aiming at the water line along the fore end and over the top of the armor belt in order to soon disable or sink her.

The foregoing considerations may suffice to show that we see no sufficient grounds for believing the Admiralty to be right in the assertion that the absence of an armor belt at the bow had no influence upon the final result of the collision in the case of the *Victoria;* still less that an armor belt could not be made more effective than it now is against the attack of a ram; and still less, again, that an armor belt of sufficient length to furnish all the buoyancy and stability necessary for safety would not afford a most powerful protection to a battleship against the destructive effects of the present rapid gun fire.

6. The sufficiency of the stability possessed by the ship.—The Admiralty say "the capsizing of the *Victoria*, under the special circumstances described, does not suggest any insufficiency of stability in the design of that vessel. The provision made was ample for all requirements. When fully laden and in sea-going trim the metacentric height was 5 feet, stability reached its maximum at an angle of 34½ degrees to the vertical, and the range of

stability was 67½ degrees." It will be observed that it is only the stability that would be possessed when the hull of the ship is absolutely intact that is here spoken of, and it is doubtless sufficient for that condition, and would enable the vessel to take considerable quantities of water on board without danger. This is not a point, however, which has great practical importance in connection with actual fighting requirements. In order to judge of the sufficiency of the stability under ordinary fighting conditions, it is necessary to know what it would be when the thinly-plated ends and compartments outside the armor belt are penetrated by projectiles. This is a factor of such great importance to the problem as to make the bare information with regard to the stability in the intact condition comparatively valueless. Whether the provision of stability was ample in the *Victoria* for all requirements, as the Admiralty assert, or is ample in existing ships of similar type, depends almost entirely, as regards the fighting requirements of a first-class battleship, upon what it is when the thinly-plated ends are penetrated. It is quite certain that damage to the ends would soon make demands upon the stability, which necessitate the provision of a large reserve in the intact condition for drawing upon, and that this reserve should be sufficient to cover not merely the heeling effect of water held over to one side by longitudinal partitions, but also the reduction of stability due to loss of buoyancy in compartments that are opened up to the sea, and the effect of speed of ship upon the quantity of water that might be admitted, and the position into which it might be forced. There is no necessity to look far in order to see that the stability could thus be seriously reduced very early in an action, and might soon become insufficient to enable the ship to be handled and fought as she should be, if not to place her in absolute peril.

7. *The steps that should be taken "to prevent the recurrence, under similar circumstances, of the conditions which, after the collision, resulted in the loss of the ship."*—The Admiralty considers that the only step requisite is to issue regulations to the fleet which will ensure "that, under special circumstances, and particularly when there is risk of collision, doors, hatches, &c., shall be kept closed

as far as possible and men stationed at any that are necessarily left open;" also, "that under certain conditions arising out of collision or under-water attack, the gun ports and other openings in the upper structure shall be closed before water can enter and endanger the stability of the ship." Now, everyone acquainted with the Admiralty and the Navy must know perfectly well that this really leaves matters as they were. Officers in command of H.M. ships are quite aware that water-tight doors, hatches, &c., require to be worked in the manner described; but the difficulty is to do it, in any emergency that may arise, so as to be effective for the purpose. The great number of water-tight doors, the difficulty of properly securing some of them, and the necessity that exists for many to be frequently open in order to carry on the ordinary work of the ship, makes it practically impossible to ensure that safety can always be relied upon by such precautions. It is true that the *Victoria* would, in all probability, not have been lost if all the water-tight doors and hatches in the fore part of the vessel had been closed; but it does not, therefore, follow that a similar disaster can be prevented in future merely by an order from the Admiralty directing that all such doors, &c., are to be closed in future in sufficient time to keep water from passing out of one compartment into another.

We would recommend that the number of water-tight doors in the various compartments be reduced; that no door which is essential to efficient water-tight subdivision, and is ever required to be left open without attendance, be fastened merely by clips; that all doors which are relied upon for safety should be capable of being closed either by a satisfactory self-acting arrangement, or by appliances for working them from a deck at a safe height above water. We would also call attention to the danger of making the safety of a ship depend upon the complete closing of a large number of small compartments. The only arrangement that can be relied upon is one of subdivision into a series of main compartments, formed by bulkheads that are carried to a deck that is high above the water line, which will be perforated as little as possible by doors, or by pipes, &c., below water. Such an arrangement as that in the *Victoria*,

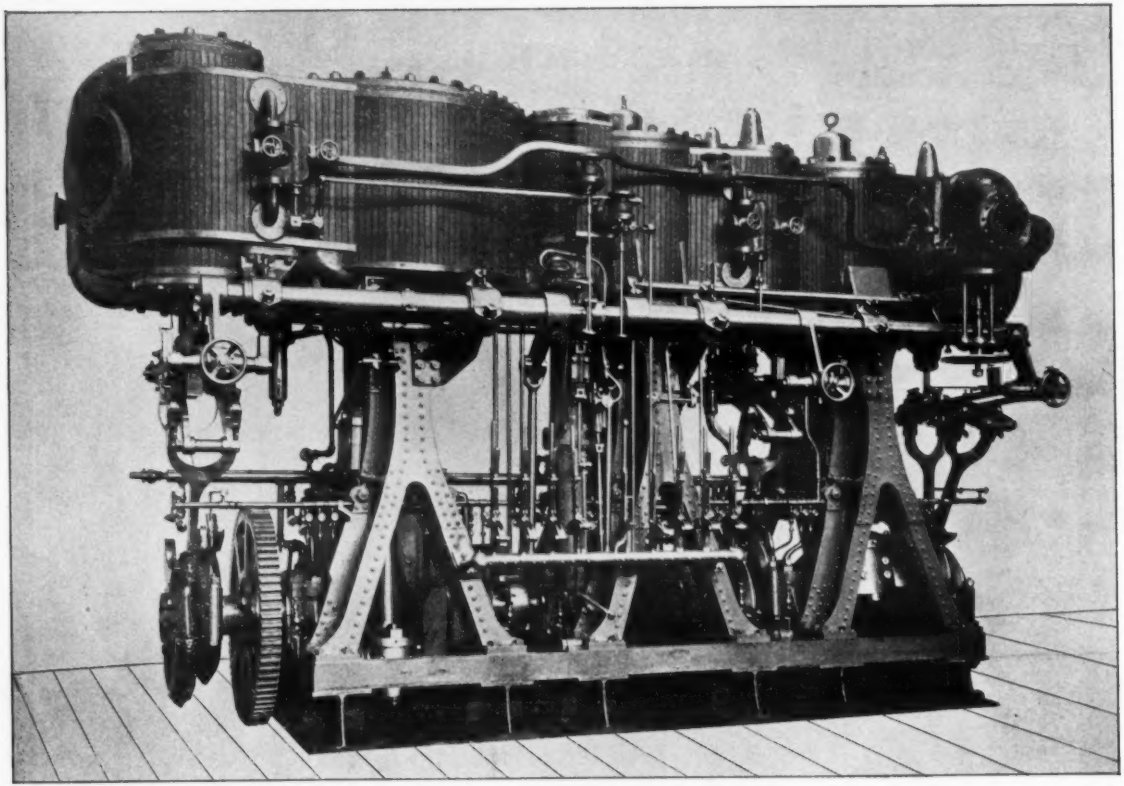
where the efficiency of some of the divisional bulkheads, which appear to have formed part of the system of water-tight subdivision, depended upon the closing of scuttles in a water-tight deck only 3 feet above water, at which the bulkheads stopped, is manifestly untrustworthy; and it is impossible for the Admiralty to remedy its defects by promulgating orders to make it work.

So far as other ships of the type of the *Victoria* are concerned, the Admiralty does not see that the necessity for any improvement is indicated. We consider, however, as the foregoing remarks show, that the result of the ramming of the *Victoria* points clearly to the necessity of making the armor belts longer in such ships if the armor is to be made really effective. This would increase the power of resistance to gun-fire, while the belts might be so fitted as to reduce the injuries likely to be caused by ramming. Water-tight flats at a small height above water, and thin bulkheads above water, are of little good against rapid gun fire. Vessels with short armor belts, such as the *Victoria* and others of her type, might, as has been pointed out, be destroyed by rapid gun fire without any penetration of their armor; so that their defensive power is not measured by the resistance to penetration of the armor they carry. They thus belong more to the type that are called protected ships than to that of armor-clads; and it would probably be more correct to classify them as such. Their names now figure in the list of first-class battleships, and make our Navy appear stronger in this class of ships than it really is. If they were classed according to their real fighting value, the necessity for adding to the number of battleships would appear stronger than it now does to those who cannot judge the relative merits of ships.

Another lesson taught by the *Victoria* disaster appears to be that the officers of such ships should be more fully instructed with regard to the probable effects of various kinds of injury than they now appear to be. It is quite certain that the officers of the *Victoria* never imagined that the ship could sink so rapidly as she did, even with many of the water-tight doors open, or that her safety depended, to the extent it did, upon the absolute closing of so many small compartments. They require to be advised and to obtain some experience as to the best mode

of treatment under different conditions of damage. Would the captains of the ships with short armor belts all know, for instance, whether it would be better or not to admit water into the ends before going into action? Has it been decided that it would be better to thus admit water and prevent changes of trim as the thin ends become perforated by projectiles or to keep water out as long as possible, and to submit to changes of trim and of heeling to one side or the other as the various compartments were opened up? The effect of loose water in the ends might be very objectionable if the speed of the ship were changing or if she were rolling to any extent; but it would exist as soon as the ends became damaged; and it is clear that the presence of a large body of water in the long unarmored ends of some of these ships would be a great source of difficulty in keeping speed and in manœuvring.

The general result of the Admiralty investigation, and of the judgment based upon it, is that there is no fault to be found with any single point connected with the construction and arrangements of the *Victoria*, or other ships of her type, for which those who conducted the investigations, or pronounce the judgment, could be held responsible; but that the whole blame is due to the one cause with which no one at the Admiralty could be in any way connected, viz., the failure to close all the watertight doors, hatches, &c., in time to prevent the disaster. In saying this we do not wish to cast any doubt upon the accuracy of the calculations which have been made, or upon the desire of the Admiralty to arrive at a fair decision upon the questions raised. It is impossible for persons who are deeply interested in these questions, and in the results of the investigation, to divest themselves of all feeling and bias, and to judge their own ideas and work from an absolutely impartial standpoint. It would probably happen in any inquiry, that if one of the parties implicated were allowed to draw up the judgment, the result would not be unfavorable to itself. Most people appear satisfied, however, that this course should be taken when the question involved is that of the efficiency of the battleships upon which the defence of the British Empire would mainly depend in the event of war.



ENGINES OF THE U.S.S. "MARBLEHEAD."

THE CONTRACT TRIAL OF THE U.S.S. *MARBLEHEAD.*

By Passed Assistant Engineer Clarence A. Carr, U. S. Navy.

The *Marblehead*, a sister ship to the *Detroit* and *Montgomery*, was built from designs furnished by the Navy Department; the machinery was built at the Quintard Iron Works, N. F. Palmer, Jr., & Co., New York City, and the hull at the works of Harrison Loring, South Boston, Mass. The contract price, $674,000, was divided into the ratios $\frac{11}{23}$ and $\frac{12}{23}$ for the parts coming respectively under the machinery and hull specifications. The requirement as to speed was that the vessel should maintain a speed of 17 knots for four consecutive hours, a premium of $25,000 being allowed for each quarter knot in excess of this speed, and a penalty of $25,000 being exacted for each quarter knot deficiency. This vessel was originally designed for a speed of 18 knots, but as no bids were received within the appropriation the speed requirement was reduced to 17 knots, thereby practically increasing the appropriation by $100,000 for the designed speed.

She is schooner rigged, without bowsprit, and has a poop and topgallant forecastle with a bridge running between them, and a flying bridge above the pilot house. She has a ram bow, with a torpedo tube discharging above the water line, and a broadside torpedo port on each side under the forecastle. A light protective or water-tight deck extends from stem to stern, and a cofferdam, intended for cellulose, extends along the berth deck on each side of the engine and boiler rooms; this cofferdam is in the upper tier of coal bunkers secured to the inboard bulkhead. A center line bulkhead extends the whole length of the machinery space, and the remainder of the water-tight subdivision is like that of larger ships of similar design, except that there is no double bottom.

There are eight boats, a steam cutter, a sailing launch, two cutters, two whale boats, a dinghy and a wherry, and, with the exception of the quarter boats, they are all stowed inboard on skid beams.

The main battery consists of ten 4-inch rapid-fire rifles, one pivoted on the topgallant forecastle, one on the poop, and the remainder mounted on projecting sponsons on each side of the gun deck. The secondary battery consists of ten Hotchkiss revolving guns.

HULL.

Material	Mild Steel.
Where built	City Point Works, South Boston, Mass.
When built	1889–1893
Length between perpendiculars, feet	257
Length over all, feet and inches	270–8
Beam, extreme, feet	37
Beam at L.W.L., feet	37
Ratio length (B.P.) to beam	6.95
Draught (moulded) forward, feet and inches } for L.W.L.	13–6
Draught (moulded) aft, feet and inches } for L.W.L.	15–6
Draught (moulded) mean, feet and inches } for L.W.L.	14–6
Displacement at load draught, tons	2,073
Displacement per inch at load draught, tons	15.65
Area immersed midship section, square feet	468
Area of L.W.L. plane, square feet	6,620
Center of gravity of L.W.L. plane aft of midship section, feet and inches	4–7
Center of gravity of ship above base line, feet	14.56
Transverse metacenter above center of gravity, feet	175
Longitudinal metacenter above center of gravity, feet	300
Coefficient of fineness on extreme dimensions	.5915
Coefficient of fineness on midship section	.87
Coefficient of fineness on L.W.L.	.70
Wetted surface, square feet	11,250

MACHINERY.

Main Engines.—There are two vertical, inverted, direct-acting three-cylinder, triple-expansion engines, each placed in a water-tight compartment. Each engine room is connected to the fire room immediately forward of it by a water-tight door in an athwartship bulkhead, and the engine rooms are connected with each other by two doors in the center-line bulkhead, one abaft the engines and one abreast the I.P. valve gear.

The high-pressure cylinder is forward, and has a working liner. All the cylinders are unjacketed, and they are each supported by two inverted Y-frames built up of plate steel and angles. The main pistons, bed plates, valve-chest bonnets, and reversing-shaft brackets and arms are of cast steel. All journals are lined with Parson's white brass. There is one piston valve for the high, two for the intermediate and two for the low-pressure cylinders, all worked by Stephenson link motion. The valves for the high and intermediate-pressure cylinders are interchangeable.

The upper ends of the high and intermediate-pressure valve stems are fitted with guides, serving as balance pistons, and the low-pressure valve stems with balance pistons, all working in cylinders connected, respectively, with the I.P. receiver, L.P. receiver, and the condenser for balancing the weight of the valves. The cut-off can be varied by a sliding block working in a slot in each reversing-shaft arm.

Each engine is fitted with a double-poppet throttle valve, moved by a lever for quick working and by a hand wheel for fine adjustment. The reversing gear consists of a steam cylinder with a hydraulic controlling cylinder, to which a hand pump is attached for reversing by hand. The working platforms are on the outboard side of each engine.

Watson's metallic packing is used in the stuffing boxes of the valve stems and piston rods.

There is a centrifugal steam separator in each main steam pipe near the engines. The following are some of the principal data:

Number of cylinders		3
Diameter of H.P. cylinder, inches		26½
Diameter of I.P. cylinder, inches		39
Diameter of L.P. cylinder, inches		63
Stroke of all pistons, inches		26
Diameter of H.P. valves (one for each cylinder), inches		14
Diameter of I.P. valves (two for each cylinder), inches		14
Diameter of L.P. valves (two for each cylinder), inches		20
Area of H.P. steam ports, maximum opening, square inches	Top	51.13
	Bottom	67.93
Area of I.P. steam ports, maximum opening, square inches	Top	102.26
	Bottom	135.86

Area of L.P. steam ports, maximum opening, square inches	Top	153.15
	Bottom	206.17
Area of H.P. exhaust ports, maximum opening, square inches	Top	102.26
	Bottom	90.58
Area of I.P. exhaust ports, maximum opening, square inches	Top	214.10
	Bottom	181.16
Area of L.P. exhaust ports, maximum opening, square inches	Top	333.44
	Bottom	300.22
Main steam pipe (9 inches diameter), square inches area		63.62
Exhaust pipe to I.P. (11 inches diameter), square inches area		95.03
Exhaust pipe to L.P. (15 inches diameter), square inches area		176.72
Exhaust pipe to condenser (20½ inches diameter), square inches area		330.06
Volume swept by H.P. piston per revolution, cubic feet		16.322
Volume swept by I.P. piston per revolution, cubic feet		35.681
Volume swept by L.P. piston per revolution, cubic feet		93.538
Clearance in H.P. cylinder, per cent	Top, 1.531 cubic feet	18.47
	Bottom, 1.258 cubic feet	15.66
Clearance in I.P. cylinder, per cent	Top, 3.121 cubic feet	17.36
	Bottom, 2.183 cubic feet	12.36
Clearance in L.P. cylinder, per cent	Top, 6.879 cubic feet	14.67
	Bottom, 5.577 cubic feet	11.96
Ratio net area H.P. to I.P. pistons		2.19
Ratio net area I.P. to L.P. pistons		2.62
Ratio net area H.P. to L.P. pistons		5.73
Piston rods, diameter, inches		4¾
Piston rods, length, feet and inches		3–10⅝
Valve stems, H.P. diameter, inches		2
Valve stems, H.P. diameter through valve, inches		1½
Valve stems, I.P. diameter, inches		2
Valve stems, I.P. diameter through valve, inches		1½
Valve stems, L.P. diameter, inches		2½
Valve stems, L.P. diameter through valve, inches		2
Balance pistons, H.P. diameter, inches		3¾
Balance pistons, I.P. diameter, inches		3¾
Balance pistons, L.P. diameter, inches		10
Connecting rods, length center to center, feet and inches		4–4
Connecting rods, diameter of upper end, inches		4¾
Connecting rods, diameter of lower end, inches		7¾
Connecting rods, thickness (sides are faced), inches		4¾
Connecting rods, diameter crosshead bolts (4), inches		2½
Connecting rods, diameter crank-pin bolts (2), inches		3½
Crossheads, actual bearing surface, square inches		185½
Crosshead pins, diameter, inches		6
Reversing gear, steam cylinder, diameter, inches		14½
Reversing gear, oil cylinder, diameter, inches		7⅛
Reversing gear, stroke, inches		22

Shafting.—The shafting is of steel throughout. The crank shafts are in three interchangeable sections connected to each other and to the line shafts by nine steel bolts. The forward sections of line shafting have enlargements to furnish seatings to the L.P. eccentrics. There are flexible couplings between the thrust shafts and the forward sections of line shafting. The after sections of line shafting are cased with brass within the stern tubes, and the forward ends are fitted with removable forged steel coupling discs to allow the shafts to be withdrawn. The propeller shafts are cased with brass only in the hanger bearings, the coupling outside the stern tube being inclosed in a stuffing box to protect it from the water.

Crank shafts, diameter, inches	10
Crank shafts, diameter axial hole, inches	5
Crank shafts, coupling discs, diameter, inches	16
Crank shafts, coupling discs, thickness, inches	$2\frac{1}{4}$
Crank shafts, coupling bolts (9), diameter, inches	$1\frac{3}{4}$
Crank shafts, journals, diameter, inches	10
Crank shafts, journals, length, inches	12
Crank shafts, length of each section (3), feet and inches	5-4
Crank pins, diameter, inches	10
Crank pins, length, inches	15
Crank pins, axial hole, diameter, inches	5
Crank webs, width, inches	13
Crank webs, thickness, inches	6
Line shafts, diameter, inches	$9\frac{3}{4}$
Line shafts, diameter axial hole, inches	5
Line shafts, diameter coupling discs, inches	$18\frac{1}{2}$
Line shafts, thickness after coupling discs, inches	$2\frac{1}{2}$
Line shafts, diameter (7) coupling bolts, inches	$2\frac{1}{16}$
Line shafts, length, feet and inches — Forward sections	13-$7\frac{3}{4}$
Line shafts, length, feet and inches — After sections	33-$4\frac{3}{4}$
Line shafts, thickness of casing, inch — At bearings	$\frac{3}{4}$
Line shafts, thickness of casing, inch — Elsewhere	$\frac{7}{16}$
Thrust shafts, diameter, inches	$9\frac{3}{4}$
Thrust shafts, diameter axial hole, inches	5
Thrust shafts, number collars, inches	11
Thrust shafts, diameter collars, inches	$13\frac{1}{2}$
Thrust shafts, thickness collars, inches	$1\frac{3}{4}$
Thrust shafts, distance between collars, inches	$1\frac{7}{8}$
Thrust shafts, length, feet and inches	9-$5\frac{3}{4}$
Thrust shafts, surface, total for both engines, square inches	1,264.6

Propeller shafts, diameter, inches	10½
Propeller shafts, diameter axial hole, inches	6
Propeller shafts, couplings, diameter, inches	18½
Propeller shafts, coupling bolts, diameter, inches	2 1/16
Propeller shafts, length, feet	30

Propellers.—The propellers are of manganese bronze, three-bladed. The blades are adjustable, and are each secured to the hub by six 2¼-inch Tobin bronze bolts. The recesses for the bolt heads are not finished to form a smooth surface fair with the boss.

Number of blades	3
Diameter, feet	11
Diameter of hub, inches	33
Pitch as set (adjustable from 11 to 14 feet), feet	12
Greatest width of blade (at a radius of 3 feet 3½ inches), inches	38
Helicoidal area of each screw, square feet	33.33
Projected area, square feet	27.52
Disc area, square feet	95.03
Pitch ÷ diameter	1.09
Helicoidal area ÷ disc area	0.351
Projected area ÷ disc area	.290
Disc area of both screws ÷ I.M.S	.406
Immersion of center at draught of 15 feet 6 inches aft, feet and inches	9–6
Distance of center of hub above lowest point of keel, feet and inches	5–11½

Condensers.—The main condensers, one for each engine, are cylindrical, and made in three principal sections. The end sections are of composition, ⅜ inch thick, the middle section of rolled-sheet brass ¼ inch thick. The water circulates through the tubes, and the inlet chest is divided, so that the circulating water passes forward through the lower half and returns through the upper half of the tubes. The auxiliary exhaust is also connected with each main condenser.

Diameter of shell, internal, feet and inches	4–11
Length over heads, feet and inches	10–1⅝
Tubes, external diameter, inch	⅝
Tubes, thickness	No. 20 B.W.G.
Tubes, exposed length, feet	8
Tubes, number in each condenser	2,923
Cooling surface, one condenser, square feet	3,823
Ratio total cooling to total heating surface	1:1.45

There is also an auxiliary condenser in each engine room, of the Wheeler type, with Knowles combined air and circulating pump. The principal dimensions of each are:

Length over heads, feet and inches	6–10½
Diameter of shell, internal, inches	17⅜
Tubes, outside diameter, inch	⅝
Tubes, thickness	No. 20 B.W.G.
Tubes, exposed length, feet and inches	5–6
Tubes, number	161
Tubes, condensing surface, each condenser, square feet	144
Combined pump:	
Steam cylinder, diameter, inches	5½
Water cylinder, diameter, inches	6
Air-pump cylinder, diameter, inches	6
Stroke, common, inches	7

Air Pumps.—There are two single-acting vertical air pumps in each engine room, each driven by a two-cylinder, vertical, inverted, compound engine. The steam cylinders are carried by wrought-steel columns supported by bed plates on the pump cylinders. The cranks are at an angle of 90°. There is a connection from each channelway through which the water of condensation can be pumped from the condenser by the feed pumps.

Diameter of H.P. cylinder, inches	6
Diameter of L P. cylinder, inches	12
Diameter piston rods, inches	1⅜
Diameter of pump cylinders, inches	14⅛
Stroke, common, inches	15
L.P. piston per double stroke ÷ air pump buckets per double stroke	34.46

Circulating Pumps.—There is a centrifugal circulating pump for each main condenser, driven by a single-cylinder, vertical, inverted, simple engine. It can be connected so as to draw either from the sea or bilge, and deliver either through the condenser or direct to the outboard delivery pipe.

Diameter steam cylinder, inches	9
Diameter piston rod, inches	1⅜
Stroke, inches	9
Diameter of runner, inches	36
Diameter of water suction, inches	12
Diameter of water discharge, inches	11

Turning Engines.—A small turning engine is placed in the passageway between each main engine and the center line bulkhead. It is a double engine, 6 inches diameter by 6 inches stroke, and turns the main engines by worm gear, which is readily disconnected. The turning-engine shaft is squared at the end and fitted with a wrench for turning by hand.

Feed Pumps.—The main feed pumps, one in each middle fire room, and the auxiliary feed pumps, one in each after fire room, are vertical duplex, and of the Blake type. The main feed pumps draw water from the feed tanks only, and deliver into the main feed pipes only. The auxiliary feed pumps are connected to draw from the sea, feed tanks, bilge, air ducts or boilers at will, and deliver into either the auxiliary feed pipe, fire main or overboard.

Auxiliary Pumps.—In each engine room there is a fire and bilge pump and an engine-room auxiliary pump, all horizontal, single, of the Blake type. In the evaporator room there is a distiller, circulating pump and an evaporator feed and tank pump of the Davidson type; also a duplex 3 by 2 by 3, and a No. 0 pump of the Blake type. The fire and bilge pumps have suctions from the sea and bilge, and deliver into the fire main and overboard. The engine-room auxiliary pumps have suctions from the sea only and deliver into the water-service pipes and fire main. The distiller circulating pump is also used for flushing the crew's closets and wash room.

The following are the sizes of the pumps:

	Steam cylinder.	*Water cylinder.*	*Stroke.*
Main feed	10	6	12
Auxiliary feed	8	5	12
Engine-room auxiliary	10	6	12
Fire and bilge	14	8	12
Distiller circulating	5½	5	10
Evaporator feed and tank	3	1⅞ feed. 1½ tank.	4

Distilling Apparatus.—The distilling plant consists of a Baird evaporator (No. 3, Type C) and a distiller, having a rated capacity of 3,000 gallons of potable water in 24 hours. The evaporator shell is a vertical cylinder, the tubes being U-shaped,

disposed in horizontal planes. There is a connection to the condenser for making up loss of feed water. The discharge pipe from the distiller circulating pump has a by-pass so that the water may be delivered into the flushing pipe without passing through the distiller. The evaporator feed and tank pump takes its feed from the distiller discharge water, and the tank part takes its suction from the filter through a water meter and discharges into the ship's tanks. A pump, with metal valves, takes the condensed water from the evaporator and discharges into the auxiliary feed pipe; and another pump has suctions from the filter and the feed pipes and discharges into tanks for the firemen's wash room.

Revolution Counters and Tell-tales—The main-engine counters are worked through gearing from the main shafts, and the same gearing works an indicator which shows the revolutions and relative movement of both main engines in each engine room. The ordinary reciprocating counters are also provided for the main engines, air pumps and circulating pumps.

Feed Tanks.—In each engine room there is a feed tank of about 315 gallons capacity. The tanks are fitted with overflow valves and sight funnels, an automatic valve in each internal suction nozzle, and perforated partitions for using filtering material. A vapor pipe from the feed tanks discharges above the level of the awnings, and is located abaft the after smoke pipe.

Steam Traps.—The drains of the main and auxiliary steam pipes, separators, radiators, evaporator, dynamo, steering engine, and steam coils on the ship's coppers are all fitted with steam traps, through which condensed steam can be returned to the feed tanks. These traps, except the one on the evaporator, are all of the Dinkel pattern; the one on the evaporator is a Baird.

Ventilating Fans.—In each engine room there is a Sturtevant blower, arranged with ducts for the forced-draft system only. There are also two fans made by the Buffalo Forge Co. for ventilating the living spaces in the ship, but arranged for exhausting the air. One of these fans is located in the dynamo room and the other in a pocket forward of the engineer's log room. The

engines for these fans are double, and are coupled directly to the fan shafts.

Diameter steam cylinder of Sturtevant fans, inches	3½
Stroke, inches	2½
Diameter piston rods, inch	⅞
Diameter of fan, inches	42

Ash Hoists.—In each fire-room hatch there is a Williamson, double-cylinder, simple, horizontal engine, cylinders 4½ inches diameter by 4½ inches stroke, for hoisting ashes.

Steering Engine.—The steering engine is of the Williamson pattern, and is placed under the water-tight deck just abaft the engine rooms. It is connected by bevel gear and shafts with the steering wheels in the pilot house and on the bridge. The wheel on the poop is for hand gear only. The engine is double, with cylinders 8 inches diameter by 7 inches stroke.

Steam Capstan.—The steam capstan is of the type made by the Bath Iron Works. It has two simple engines, 9 inches diameter by 9 inches stroke, with the cranks at right angles. In addition to the regular purchase, which is sufficient under ordinary circumstances, there is an arrangement by which an additional worm and wheel can be thrown in gear, giving a double purchase for use in an emergency.

A steam winch built by the American Ship Windlass Co. is located in the middle fire room hatch.

Workshop Machinery.—The engineer's workshop is located on the gun deck under the forecastle. It contains a vise bench, a 10-inch shaping machine, a 12-inch lathe, and a double-geared drill, all driven by a 5 by 6 engine.

Electric Light.—The vessel is lighted throughout with electric light, and has, in addition, two search lights on the bridge. The plant consists of two Thomson-Houston dynamos, each of 80 volts and 200 amperes, each operated by an Edison vertical engine designed for a working pressure of 80 pounds per square inch. The engines are double, and the cylinders are each 7 inches diameter and 5 inches stroke.

The ship also has a complete equipment of call bells and speaking tubes, shaft and rudder indicators, and fire and water alarms.

BOILERS.

There are three cylindrical, double-ended, horizontal, return-tube boilers, and two single-ended boilers of the same type. Each double-ended boiler has four and each single-ended boiler two corrugated furnaces. The axes of the boilers are fore and aft, one double-ended and two single-ended boilers (placed end to end) being on the starboard side, and two double-ended boilers on the port side. The boiler space is divided by the athwartships and center-line bulkheads into six compartments, with a fire room in each compartment. There are two furnaces in each forward and after, and four in each middle fire room. There are two smoke pipes. The front and back heads of all boilers are curved at the top. The longitudinal shell seams are treble-riveted with double butt straps. Circumferential joints are lapped and double riveted. Joints in furnaces and combustion chambers are single-riveted. The furnaces are fitted with rocking grates. Water can be circulated when raising steam by using the auxiliary feed pumps. Internal feed pipes are arranged to distribute the feed water through the boilers. Each boiler has a main and an auxiliary stop valve, two spring safety valves, one sentinel valve, two feed-check valves, one bottom-blow valve, one drain valve, two steam gauges, two glass water gauges and four gauge cocks.

The systems of main and auxiliary feed pipes are independent. The boilers and steam and exhaust pipes are clothed with a spongy preparation of asbestos, called fire felt. The outer covering of the boilers is galvanized iron, and of the pipes, canvas.

BOILERS.

	A and B.	*C and E.*	*D.*
Length, feet and inches	18–1	~~18–8½~~ 9–7½	~~9–½~~ 18 – 8½
Diameter, feet and inches	11–8	11–8	11–8
Number of furnaces	4	2	4
Number of combustion chambers	4	2	4
Length of furnaces, feet and inches	6–4⅛	6–⅞	6–8⅞
Length of tubes between sheets, feet and inches	6–3	5–11½	6–7
Number common tubes	476	238	476
Number stay tubes	156	78	156
Tube-heating surface, square feet	2,381.1	1,132.4	2,497.4
Plate-heating surface, square feet	379.64	188.6	397.04
Grate surface, square feet	89.4	42.5	94.35

	A and B.	*C and E.*	*D.*
Steam room, six inches above tubes, cubic feet	397.5	190.	403.
Water surface, six inches above tubes, square feet	183.	91.	189.
Diameter of safety valves, inches	5	3	5
Diameter of main stop valves, inches	$6\frac{3}{4}$	5	$6\frac{3}{4}$
Diameter of auxiliary stop valves, inches	5	5	5
Volume furnaces and combustion chambers, cubic feet	284	140	292
Steam pressure, pounds			160
Tubes, outside diameter, inches			$2\frac{1}{4}$
Tubes, spacing horizontally, inches			$3\frac{1}{2}$
Tubes, spacing vertically, inches			$3\frac{1}{4}$
Tubes, thickness of common, No. 12 B.W.G., inches			.109
Tubes, thickness of stay, No. 6 B.W.G., inches			.203
Furnaces, greatest internal diameter, inches			$44\frac{7}{8}$
Furnaces, least internal diameter, inches			42
Combustion chambers, depth, inches			27
Combustion chambers, width			$56\frac{1}{2}$
Thickness of shell plates, inches			$1\frac{1}{64}$
Thickness of head, inches: Top			$\frac{15}{16}$
Thickness of head, inches: Bottom			$\frac{3}{4}$
Thickness of tube sheets, inch			$\frac{3}{4}$
Thickness of combustion-chamber plates, inch			$\frac{1}{2}$
Thickness of furnaces, inch			$\frac{9}{16}$
Diameter of rivets in shell, inches			$1\frac{1}{16}$
Pitch of screw stays, inches			7
Diameter of screw stays, inches			$1\frac{3}{16}$
Number and diameter of braces above tubes (8), inches			$2\frac{1}{4}$
Number and diameter of braces to back tube sheet (4), inches			2
Number and diameter of braces around lower manhole, inches: 1			2
Number and diameter of braces around lower manhole, inches: 2			$1\frac{1}{2}$
Diameter of smoke pipes, feet and inches			5–7
Area of each smoke pipe, square feet			24.48
Height of smoke pipes above grate, feet			$57\frac{1}{2}$
Totals for all boilers:			
Tube-heating surface, square feet			9,524.40
Plate-heating surface, square feet			1,153.52
Total heating surface, square feet			11,057.92
Grate surface, square feet			358.17
Area through tubes, square feet			54.44
Area over bridge walls, square feet			49.12
Area of smoke pipes, square feet			48.96
Area of water surface, square feet			737
Volume of steam room, cubic feet			1,578
Volume of furnaces and combustion chambers above grates, cubic feet			1,068
Ratios:			
Tube H.S. to G.S.			26.60 to 1
Plate H.S. to G.S.			3.22 to 1

Total H.S. to G.S.	29.82 to 1
Area through tubes to G.S.	.152 to 1
Area water surface to G.S.	2.08 to 1
Steam room, per square foot G.S., cubic feet	4.41
Volume combustion chambers and furnaces per square foot G.S., cubic feet.	2.98

Forced Draft.—The forced draft is the Kafer ash-pit system, air being supplied by one Sturtevant blower in each fire room. They take air from the fire rooms and deliver through ducts to the ash pits and furnace fronts. Suitable gear is fitted to the furnace doors, so that they can not be opened without closing a damper in the air duct.

	Middle fire rooms.	*Other fire rooms.*
Diameter of engine cylinders (2), inches	4	3½
Stroke, inches	3	2½
Diameter of fan, inches	48	42
Width of fan, inches	22	15
Area induction nozzle, square inches	707	594
Area eduction nozzle, square inches	624	432

Coal Bunkers.—There are 23 coal bunkers, of a combined capacity of 340 tons of 43 cubic feet, of which 100 tons is below and 240 tons above the water-tight deck. There are seven bunkers on each side, above the water-tight deck, and each bunker has one scuttle to the gun deck for receiving coal. Seven escape scuttles are fitted for filling the lower bunkers, and two lead into each of the middle fire rooms. A trolley runs through each of the upper tiers of bunkers for convenience in transporting coal.

WEIGHTS.

Propelling machinery, including all the auxiliary machinery mentioned in this article (except capstan, steering, winch, workshop and dynamo engines), together with water in boilers, pipes, condensers and stern tubes, tons	473.23
The most important detailed weights are:	*Pounds.*
Bed plates, shaft bearings, brasses and caps	20,382
Thrust bearings	4,888
Spring bearings	1,416
Stern and bracket bearings	9,638
Frames and crosshead guides	15,186
Cylinders, covers, stuffing boxes, relief and starting valves, etc.	60,033
Pistons, with rods and nuts	8,978
Valves, with stems and crossheads	4,732

	Pounds.
Links, eccentric rods and straps	6,798
Connecting rods	9,388
Crank shafts and eccentrics	16,166
Line shafts, forward sections	5,728
Thrust shafts	5,648
Line shafts, after sections	18,912
Propeller shafts	13,555
Propellers	11,496
Reversing engines, shafts, brackets and arms	9,625
Turning engines and gear	4,302
Separators	1,832
Feed tanks	3,218
Main condensers	25,898
Auxiliary condensers	4,606
Throttle valves	1,048
Air pumps and connections	13,272
Circulating pumps and connections	10,188
All sea valves	4,174
Main steam and exhaust pipes in engine rooms	9,008
Main steam pipes in fire rooms	5,025
Auxiliary steam and exhaust pipes in engine rooms	9,909
Auxiliary steam and exhaust pipes in fire rooms	9,285
Working levers and gear	2,610
Main bilge pumps	4,010
Engine room auxiliary pumps	2,350
Engine room blowers and ducts	5,172
Drain pipes and traps	2,776
Clothing and lagging	13,559
Boilers with attachments	367,799
Uptakes	39,419
Smoke pipes	24,699
Fire-room blowers and ducts	17,885
Main feed pumps	3,978
Main feed pipes	3,322
Auxiliary feed pumps	4,620
Auxiliary feed pipes	3,100
Boiler stop valves	3,003
Boiler safety valves	1,891
Distilling apparatus	3,840
Workshop machinery	3,614
Steam winch	6,752
Steam capstan	17,864
Steering engine	10,164
Dynamos and engines	14,593
Ship ventilating fans	2,874
Water in boilers, 4½ inches above tubes	187,704
Water in condensers	6,392

REVOLUTIONS FOR FIFTEEN-MINUTE PERIODS OVER MEASURED COURSE ON LONG ISLAND SOUND.

TIME.	Average Revolutions per minute for each 15 minute period.			REMARKS.
	Starboard.	Port.	Mean.	
A. M.				h. m. s. Counter readings at 10 09 30 A.M.
10 09 30				Starboard 10,665
10 25	179.2	176.5	177.85	Port 638,899
10 40	179.0	172.4	175.7	h. m. s. Counter readings at 12 07 12 P.M.
10 55	177.8	171.4	174.6	Starboard 31,663
11 10	178 6	172.9	175 75	Port 659,264
11 25	176.6	172.6	174.6	h. m. s. Counter readings at 12 27 55 P.M.
11 40	178.0	172.2	175.1	Starboard 35.288
11 55	180 8	172.4	176 6	Port (at 12–27–40) 662,800
P. M.				h. m. s. Counter readings at 2 17 35 P.M.
12 07 12	176.5	173.2	174.85	Starboard 54.983
				Port 681,900
12 27 55				h. m. s.
12 43	182.3	171 7	177.0	Revolutions of stb'd eng. in 3 47 22 40,693.
12 58	178 5	174.2	176.35	h. m. s.
1 13	178.0	172 6	175.3	Revolutions of port eng. in 3 47 37 39,465.
1 28	180.3	175 3	177.8	$\frac{40.693}{227.3667} = 178.975$
1 43	179.0	172.1	175 55	$\frac{39.465}{227.6167} = 173.380$
1 58	178 0	174.1	176.05	Mean = 176.1775
2 13	181.7	174.0	177.85	
2 17 35	179.3	182.2	180 75	

TRIAL.

The official trial took place December 7, 1893, and consisted of a run each way over a course 36 miles long, on Long Island Sound between Saybrook Point and Stratford Shoal Light. The depth of water on this course was about 17 fathoms.

Indicator cards were taken every half hour from each main cylinder, and once an hour from the circulating pumps. Cards were taken after the trial from the air pumps, bilge pumps, feed pumps, and blowers, under as nearly as possible the conditions of the trial. The indicator gear of the starboard I.P. cylinder was disabled at the beginning of the first run, and the mean effective pressure in that cylinder was calculated by using a

constant determined from the port engine. The indicators used belonged to the ship's outfit, and no corrections have been applied. Both auxiliary condensers were in use, and received the exhaust from all the auxiliary machinery, except the main air and circulating pumps, which exhausted into the main condensers. All main and auxiliary machinery worked most satisfactorily in all respects.

Reciprocating counters, which could be thrown in and out of gear electrically, were used for recording the revolutions of the main engines during intervals when cards were being taken. They worked satisfactorily for this purpose, and would undoubtedly furnish a reliable method of recording the exact number of revolutions during any interval.

The coal used was hand picked Pocahontas, and bagged so that a reliable estimate was obtained of the coal used on the trial. The safety valves of the forward boilers were blowing constantly, and at times very strongly, during the trial, and those on the after boilers were blowing moderately at intervals.

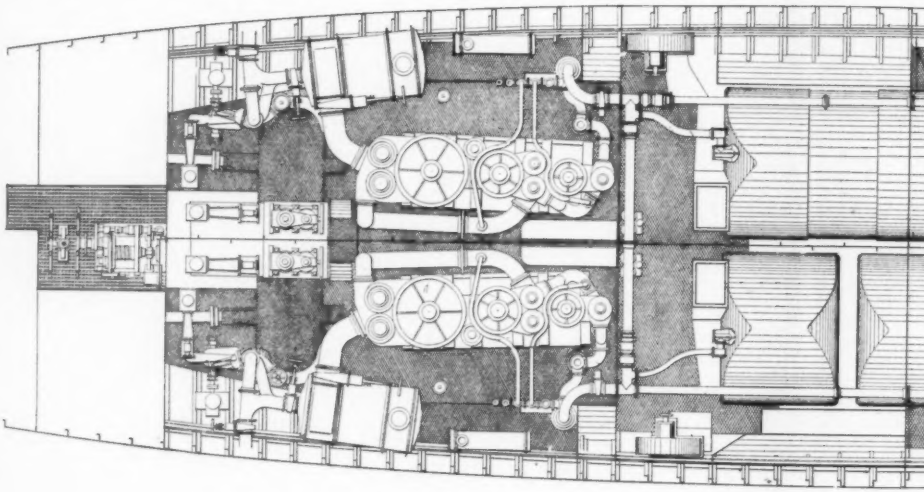
DATA OF TRIAL.

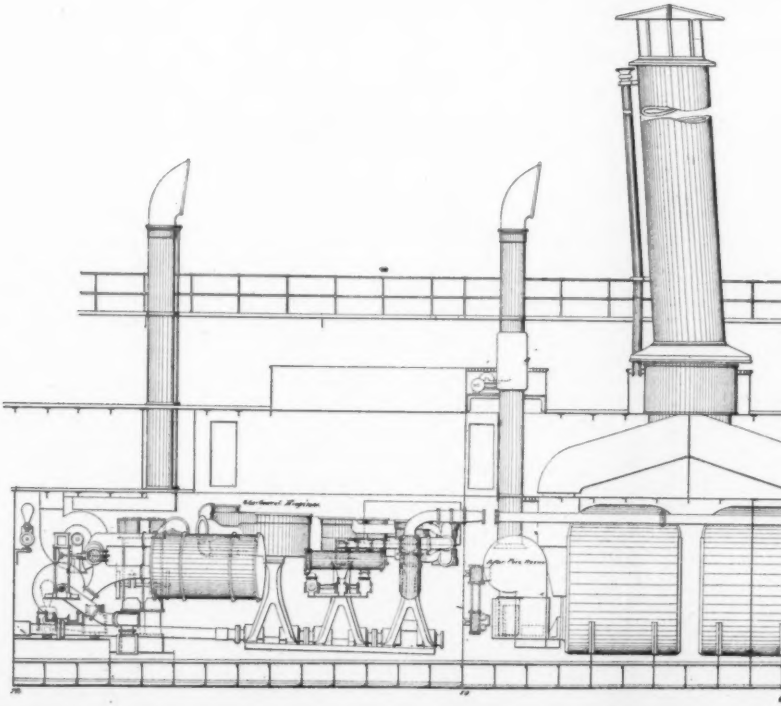
Draught at beginning, feet and inches	Forward	13-6	14-6
	Aft	15-6	
Draught at end, feet and inches	Forward	13-1½	14-3½
	Aft	15-5½	
Draught, mean, for trial, feet and inches	Forward	13-3¾	14-4¼
	Aft	15-5¾	
Displacement, at mean draught for trial, tons			3,954
Area immersed midship section, square feet			464
Wetted surface, square feet			11,196
I.H.P. total per 100 square feet wetted surface			48.68
Average speed in knots			18.44
Slip (mean of both screws), per cent.			12.08
$S^3 \times$ area midship section $\div$ I.H.P			547.93
$S^4 \times D.^{\frac{2}{3}} \div$ I.H.P			190.36
Grate surface (during trial only), square feet			414.17

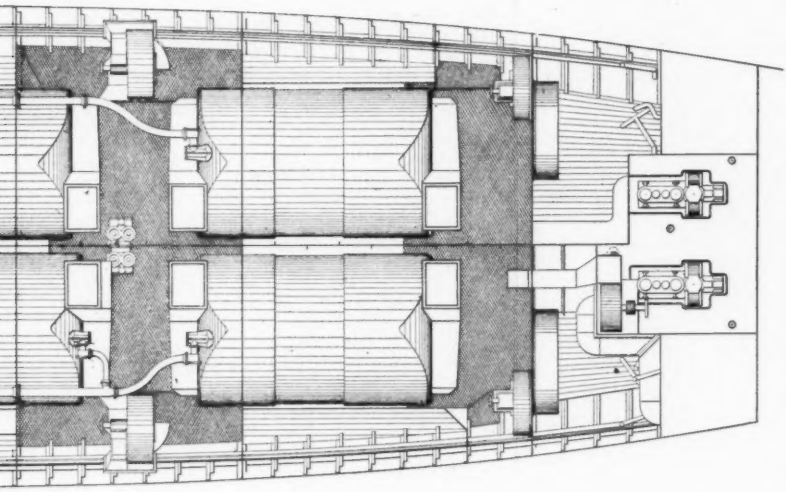
SYNOPSIS OF STEAM LOG.

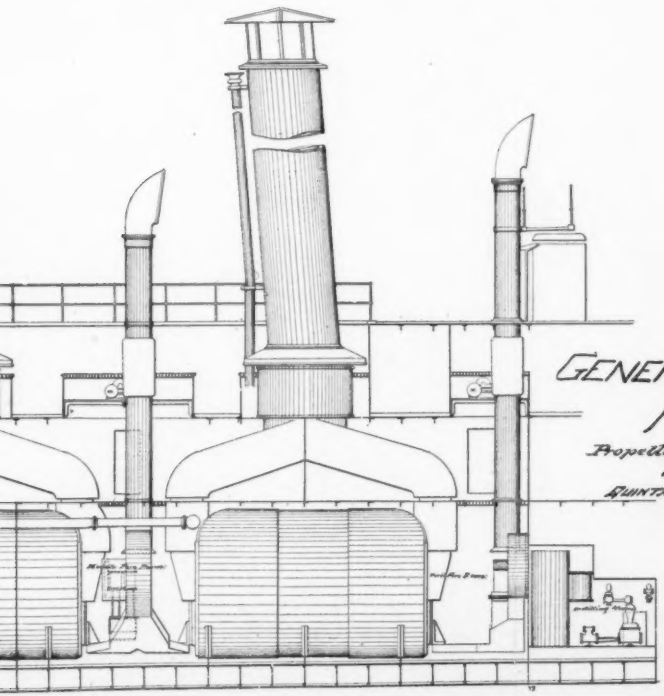
	Starboard.	*Port.*
Steam at boilers, test gauge	164.5	164.5
Steam at engine (gauge)	163.7	160.
Steam at first receiver (absolute)	77.6	85.1
Steam at second receiver (absolute)	30.9	33.5

No.134.









CRUISER No. 11.

GENERAL ARRANGEMENT OF MACHINERY.

Propelling Machinery of 5400 I.H.P.

Cruiser of 2000 Tons.

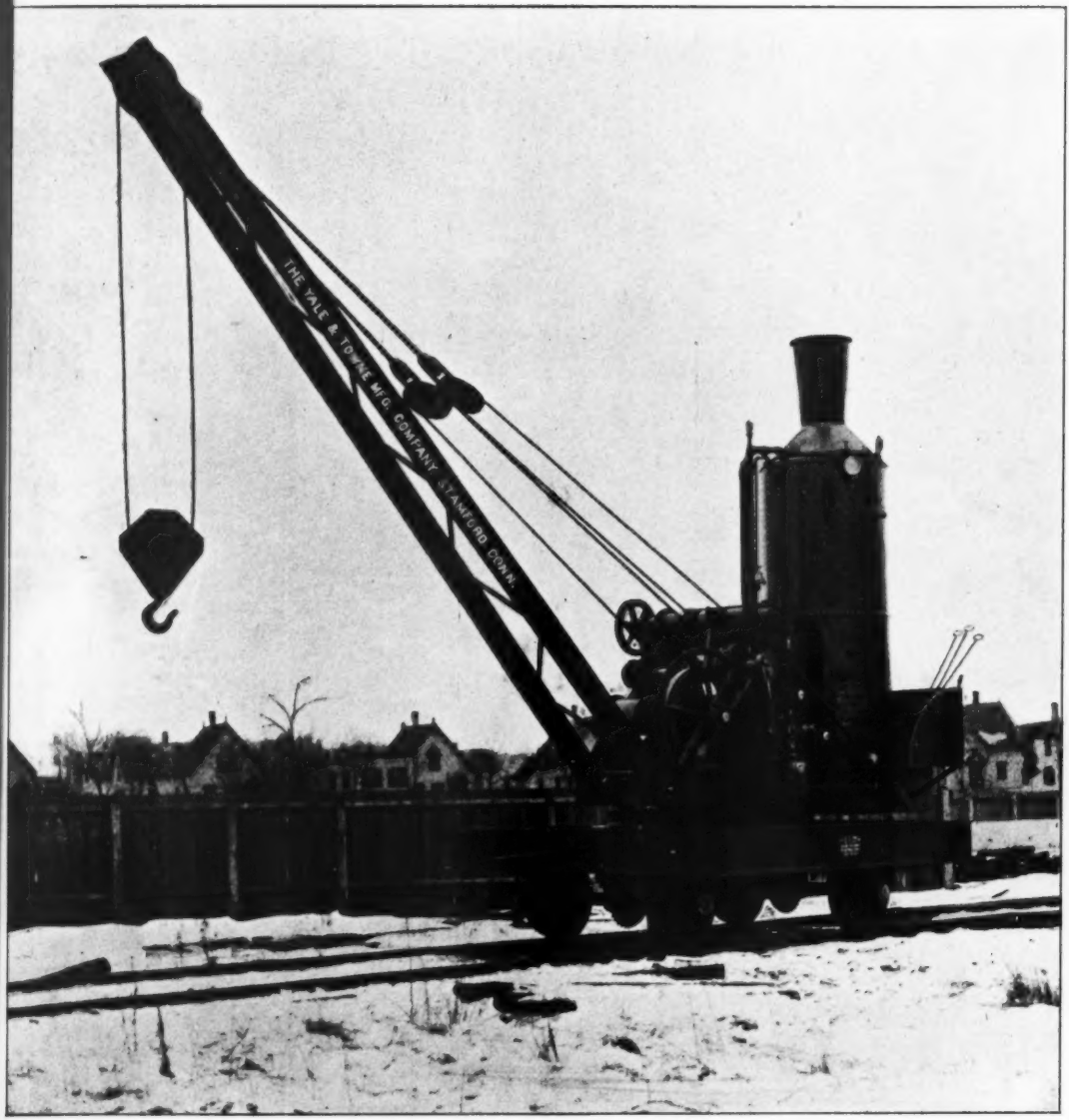
Quintard Iron Works, New York.

Scale, 1/2 1 2 3 4 5 6 7 8 9 10 Feet.

		Starboard.	*Port.*
Vacuum in condenser in inches of mercury		26.2	25.9
Opening of throttle		Wide.	Wide.
Piston speed in feet per minute		775.58	751.31
Revolutions of main engines per minute		178.98	173.38
Revolutions, mean, of both engines		176.18	
Revolutions of air-pump engines per minute		157.20	161.49
Revolutions of circulating pumps per minute		155.70	164.41
Revolutions 4 × 3 blowers per minute		450.40	560.25
Revolutions $3\frac{1}{2} \times 2\frac{1}{2}$ blowers per minute, forward fire rooms		689.60	699.56
Revolutions $3\frac{1}{2} \times 2\frac{1}{2}$ blowers per minute, after fire rooms		566.	663.46
Double strokes bilge pumps per minute		32.85	39.14
Double strokes feed pumps per minute		21.75	
Cubic feet swept through per minute by L.P. piston per I.H.P. of main engines		6.30	6.13
Temperature in degrees Fahrenheit	Steam at H.P. cylinder	372.	
	Engine rooms	89.7	
	Injection	44.5	
	Discharge	84.6	88.
	Feed tank	115.7	123.
	Feed in fire rooms	120.	
	Fire rooms, mean	117.	
Steam cut off in fraction of stroke from beginning	H.P.	.71	.71
	I.P.	.71	.71
	L.P.	.68	.68
Mean pressures in cylinders	H.P.	61.89	61.04
	I.P.	31.66	32.11
	L.P.	13.46	14.50
	Aggregate equivalent referred to L.P.	36.37	37.40
I.H.P.	H.P. cylinder	789.84	754.05
	I.P. cylinder	882.27	866.90
	L.P. cylinder	983.75	1,025.90
	Collective, each engine	2,655.86	2,646.79
	Collective, both engines	5,302.65*	
	Air pump	15.65	15.95
	Circulating pump	9.95	10.51
	Feed pumps	22.10	
	Auxiliary condenser pumps, estimated	3.	
	Bilge pump	1.04	1.23
	Blower engines	54.20	
	Dynamo engines, estimated	14.40	
I.H.P. collective, main engines, air, circulating and feed pumps		5,376.78	
I.H.P. collective, all main and auxiliary engines		5,450.65	
I.H.P. collective, all machinery, per square foot of G.S.		~~13.16~~	13.22

* The corrected I.H.P. was 4,863.30.—ED.

I.H.P. collective, all machinery, per square foot of H.S.	0.49
I.H.P. per ton of propelling machinery, boilers, and water	11.52
I.H.P. main engines, air, circulating and feed pumps, per square foot G.S.	12.99
I.H.P. main engines, air, circulating and feed pumps, per square foot H.S.	.48
Square feet heating surface per I.H.P.	2.03
Square feet cooling surface per I.H.P.	1.41
Air pressure, in inches of water, in ash pits	1.08
Air pressure, in inches of water, in furnace fronts	0.88
Pounds of coal burned per hour	15,690.43
Pounds of coal per hour, per square foot G.S.	37.88
Pounds of coal per hour, per square foot H.S.	1.42
Pounds of coal per hour, per I.H.P., all machinery.	2.88
Pounds of coal per hour, per I.H.P. main engines, air, circulating and feed pumps	2.92



TEN-TON STEAM LOCOMOTIVE CRANE.

THE YALE & TOWNE MANUFACTURING COMPANY,

CRANE BUILDERS,

STAMFORD, CONN.

MODERN CRANES.

By B. H. Warren, Ass't Eng'r, U. S. Navy (Retired), Manager Crane Dep't, the Yale & Towne M'f'g Co.

LOCOMOTIVE CRANES.

Usage has restricted the term "locomotive crane" to a hoisting machine which is self-propelling and which usually travels on tracks laid on the ground, as distinguished from the "traveling crane," whose tracks are overhead. Locomotive cranes, in addition to the functions of hoisting and of locomotion, have usually a third function, viz: that of rotation. They are thus capable of lifting a load, and of rotating and traveling with the load suspended. Their motive power consists, nearly always, of a steam boiler on the crane, the steam from which is utilized in one or more pairs of engines also attached to the crane. Thus constructed, the crane is entirely self-contained and capable of service wherever tracks are provided on which it can travel. A few electric-locomotive cranes have been built, operated by electric motors furnished with current taken by trolley from an overhead wire, but as a rule this construction has no advantages, but rather many disadvantages, as compared with the self-contained machine, which carries its own steam generator and engines.

In Europe locomotive cranes are in vastly greater use than in America, owing in part to the difference in methods of handling and shipping heavy material, but due also to the fact that America is as yet far behind Europe in the appreciation and use of cranes of every kind. Notwithstanding this fact, American users of locomotive cranes already demand from them a far higher efficiency and endurance than is expected in other countries where such cranes have been long in use. The Yale & Towne M'f'g Co. was the first American maker to undertake the adaptation of the locomotive crane to American requirements. It began by

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purchasing working drawings from English, French and German crane makers and by importing a crane built by one of the best English makers, its purpose being to avail itself of the latest and best European products. Its first cranes built on these lines failed to satisfy the requirements of users, and all of the drawings and patterns pertaining to them were soon permanently discarded. The new designs which followed were much better, and the cranes built from these gave fair satisfaction. Almost immediately, however, American users began to demand greater power, higher speeds, and, especially, the substitution of better forms of clutches in place of those employed in English cranes. The endeavor to meet these demands has resulted in a steady evolution of the locomotive crane during a period of more than ten years, and in the development of designs which are radically different, in almost every detail, from those originally adopted, and which are believed to be greatly in advance of the best foreign practice. The illustrations and descriptions which follow relate to the locomotive crane as thus developed and now built by the Yale & Towne M'f'g Co.

The photographic picture is taken from a ten-ton crane with variable radius gear, and shows the general construction, except that in many cases a house or roof of corrugated iron is built over the mechanism to protect it and the operator from the weather. It will be seen that the main platform of the crane is of steel beams framed together, to which is attached, underneath, the boxes for the axles of the truck wheels, and in the center of which is fixed a heavy center casting on which is mounted the rest of the structure, including the friction slip-ring whereby the crane is rotated upon its axis. Above this is the rotating bed or housing on which all of the mechanism is assembled. Mounted on the rear of this bed is the steam boiler, and between this and the mechanism stands the operator, with all of the controlling levers within his convenient reach. The motive power is furnished by a pair of vertical engines connected by a crank shaft carried by the two inclined frames forming a part of the rotating bed or housing. Power is taken from this crank shaft for each of the three functions, hoisting, rotation and propelling, by means

of suitable gears and clutches. On top of the housing is a pair of winding drums for varying the angle of the boom in order to change the radius of the crane, and to raise or lower the head of the boom to enable it to pass under obstructions. The truck is provided at each end with a coupling bar, whereby the crane may be coupled to cars and may be used as a shifting engine, for which purpose it is very frequently employed. For all capacities up to ten tons these cranes are usually constructed to travel on tracks of standard gauge, in order to utilize the ordinary tracks in yards and buildings. For cranes of larger capacity, or where exceptional stability is required, a broader gauge is used, usually of seven feet.

Plate I contains three views of a similar crane, viz: A side elevation, an end elevation and a plan.

Referring to these it will be seen that the motive power, comprising a boiler and a pair of engines, is all mounted upon the rotating bed and has no connection with the main platform or truck of the machine except through the center pin or axis. Vertical engines are found preferable to horizontal ones, as causing less vibration to the crane. This is always an important factor, and is particularly so when a crane is to be used upon a bridge or other structure which might be injuriously affected by any excessive vibratory action. At least two engines, coupled at right angles, are necessary in order to insure prompt starting from any position and to equalize the power. A separate pair of engines might be used for each of the three functions, but this would largely increase the weight, cost, and complexity of the mechanism. Experience has established the fact that it is better to have a single pair of engines, large enough to furnish all power required, and to utilize this power for all of the several functions.

A link-motion valve gear is used, which affords nice adjustment of speed and power, and which enables the motion of the engines to be quickly reversed. The distribution of power is further controlled by means of clutches, of which there are always one for transmitting power to the hoisting train, two for operating the rotating gear in any direction, and usually one for the propelling gear, the motion of which latter is reversed by

reversing the engines. When desired, two clutches are provided for the traveling or propelling gear, but experience has shown that it is preferable to control the direction of travel by reversing the engines. For rotating, on the contrary, two clutches are needed, as it is frequently desired to rotate in either direction while hoisting is being effected. The function which requires the greatest power is that of traveling, especially if the crane be used as a switching engine, which is frequently the case. The power needed for this purpose is ample to effect both hoisting and rotating simultaneously. In practice the motive power is usually made ample to effect all three functions at once. It may be added that a single pair of engines is much more economical in power than three separate pairs would be, which is an important item, as the crane must carry its own supply of water and fuel.

Referring now to the several functions, they may be described as follows: Power is taken from the first or crank shaft by a clutch gear driving a large spur wheel attached to the hoisting barrel, the latter provided also with a large strap brake. The load is suspended on either wire, rope or chain, preferably the former, for cranes of ten tons and upward, and the drum or barrel has sufficient capacity to receive all of the chain or rope in a single wrap without overlapping. The load is held and controlled, in lowering, by a powerful strap brake, operated by a foot lever, and of such construction as to easily admit of wide variation in the rate of speed of lowering without danger of the load accelerating too quickly and getting away from the operator. With the engine in continuous motion the operator releases the strap brake by his foot, and effects hoisting by moving the lever of the hoisting clutch. By slightly releasing the latter he may permit slipping to take place equal to the speed of the shaft, thus neutralizing the hoisting power and holding the load stationary at any point, or may accomplish the same result by simultaneously throwing on the strap brake and throwing out the hoisting clutch. He may also control the motion of the load by stopping or changing the speed of the engines either by means of the reversing lever, connected with the link-motion,

or by means of the throttle valve. This facility of control enables an expert operator to manipulate the crane with great rapidity and yet with perfect smoothness and safety.

The rotating mechanism has often been a troublesome feature in these cranes, but by the adoption of the "Grafton patent slip ring," used in all locomotive cranes built by the Yale & Towne M'f'g Co., it is made as reliable, smooth and safe as the other functions. This device consists in a large ring, having spur teeth on its periphery and fitting loosely upon a turned path or bed provided for it on the main frame or truck. The rollers which support the rotating bed bear on top of this loose ring, and the friction thus developed tends to prevent its turning. A pinion, shown in the side elevation of Plate I, engages with this slip ring, and is driven by a bevel wheel, on the upper end of its vertical shaft, which gears into one or the other of two similar wheels mounted on a transverse horizontal shaft, each connected thereto by a friction clutch. With this shaft rotating continuously in either direction, rotation of the crane is effected in any direction by throwing in either one or the other of these two clutches, thereby causing the pinion to rotate. The effect of this is to cause the pinion to tend to travel upon the periphery of the slip ring, and this will be the result if this motion be made slowly and gradually. If, however, the rotating power be thrown suddenly into gear, the inertia of the superincumbent parts will be greater than the frictional resistance to the slipping of the slip ring, which latter will, therefore, rotate backward until the inertia of the mass has been overcome, when the crane will begin to rotate and the ring will cease to slip. These several parts are so nicely adjusted that, by this simple means, all tendency to shock is avoided, and rotation may be effected in either direction or may be reversed as frequently and as quickly as desired without any danger of breaking or even straining any part of the mechanism. The gain in time and convenience to the operator, where this device is used in connection with good clutches, and the entire immunity it affords from shock and danger, is very apparent when the crane is seen in service. A crane thus constructed, as to its rotating gear, is far safer, more convenient,

and more rapid in action than one not provided with such frictional safety device.

The traveling mechanism is driven by power taken from a horizontal transverse shaft, by either one or two clutches, operating through bevel gears to drive a vertical shaft located in the center of the machine, and passing downward through the hollow steel center pin which unites the upper and lower beds or frames, and forms the axis of rotation, the lower end of this vertical shaft carrying a bevel pinion gearing into a bevel wheel mounted on a horizontal longitudinal shaft between the two truck axles. Each end of this shaft carries a bevel pinion, gearing into a bevel wheel on the respective truck axles. The power so transmitted thus operates to rotate the truck wheels and propel the crane. Owing to the overturning tendency of the load, which may be such relatively to the counterbalance as to throw the whole weight on one pair of truck wheels, and entirely to leave the other pair unloaded, and also to the fact that the load may be at any point in the whole circle of rotation, it is necessary to apply power to all four of the truck wheels to make certain that there shall always be sufficient tractive force to propel the crane under all conditions, and especially on tracks which are poor or wet, and also on curves and grades. Formerly, chains of various kinds were used for transmitting power to either or both of the truck axles, but this device has been found unreliable and objectionable. Chains so used inevitably stretch and wear, thus developing a slack which permits the engines to race while the slack is being taken up, and which causes a violent shock to the whole mechanism when this has been done and the motive power thus suddenly applied to the truck wheels. The construction shown eliminates these serious faults, and, when controlled by an effective clutch, enables the traveling functions to be started and stopped without shock, smoothly and at any desired rate of acceleration.

A fourth function is now usually provided, especially in cranes of the larger sizes, viz: a variable radius gear. The purpose of this is to change the radius of the hook, by raising or lowering the head of the boom. This enables the stability of the crane to

be increased for heavy loads by shortening the radius, and its "reach" to be increased for light loads by lengthening the radius. It is also useful as enabling the boom to be lowered to pass under bridges or doorways. This mechanism consists of a drum mounted on top of the housing, and suitably connected by clutches with the motive power, whereby the wire rope guys, which support the outer end of the boom, may be wound or unwound to vary their length. This device is usually not required except in cranes having a capacity of five tons and upwards.

Obviously the form of friction clutch is an important factor in these machines. In European practice simple "jaw" clutches are largely used, notwithstanding their rudeness and tendency to cause shock and injury to the mechanism unless the motion of the parts is nearly stopped before the "jaw" clutches are engaged. "Cone" clutches are also used in Europe, but with indifferent success, because of the small friction surface they afford, the severe pressures they produce, and the resulting rapidity of wear. To overcome these difficulties the Yale & Towne M'f'g Co., after long experimentation, has developed a modified form of the Weston friction clutch which perfectly meets the requirements, and which has proved thoroughly satisfactory.

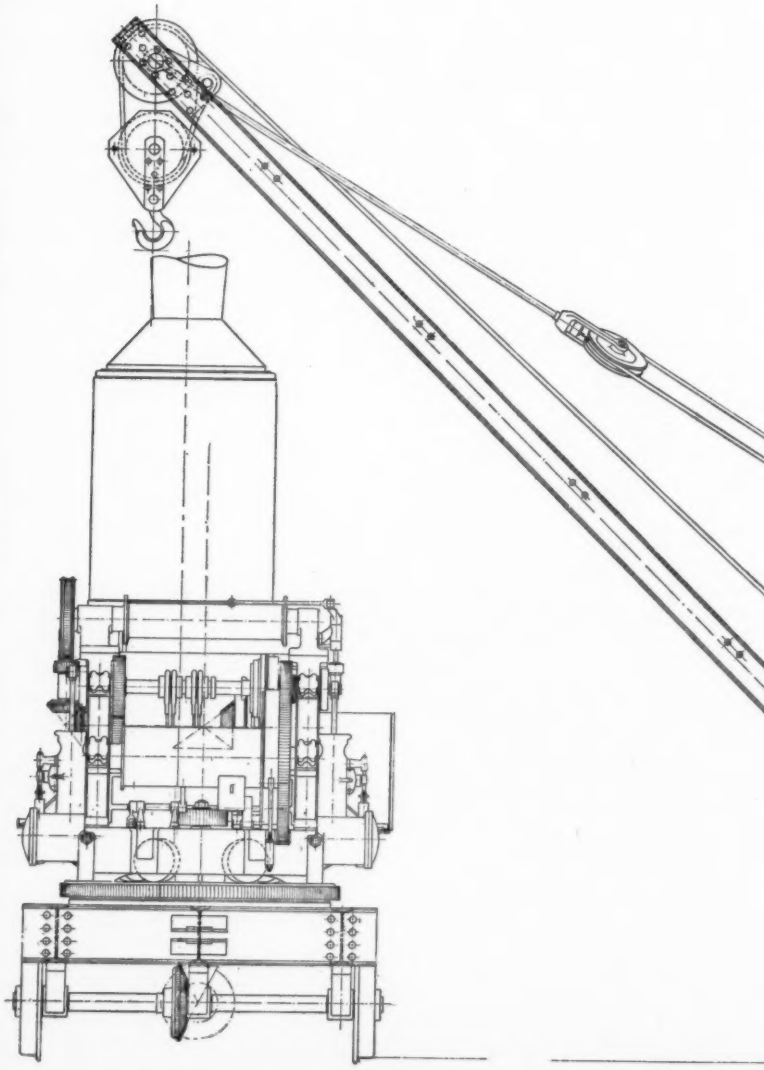
The construction of this clutch is shown by Plate II. It consists of a disc mounted on a shaft carrying a friction ring of iron or steel, clamped between two similar rings formed of wooden segments contained within proper recesses or pockets of two lateral carrying rings. The latter are connected together by a series of bolts, parallel with the shaft, whereby they may be caused to clamp or pinch the central steel ring by the action of two or more nipping levers, operated by a sliding cone on the shaft, the motion of which raises or lowers the ends of these levers. Adjusting nuts on the ends of the bolts enable these rings to be properly set, and the wear of the wooden discs to be taken up. The friction surfaces being few in number, and all being true planes rotating on the same axis, very slight motion suffices to release or engage them. The parts are so attached that, when the cone is fully under the levers, the friction surfaces are so tightly locked that slipping cannot occur. By moving the cone

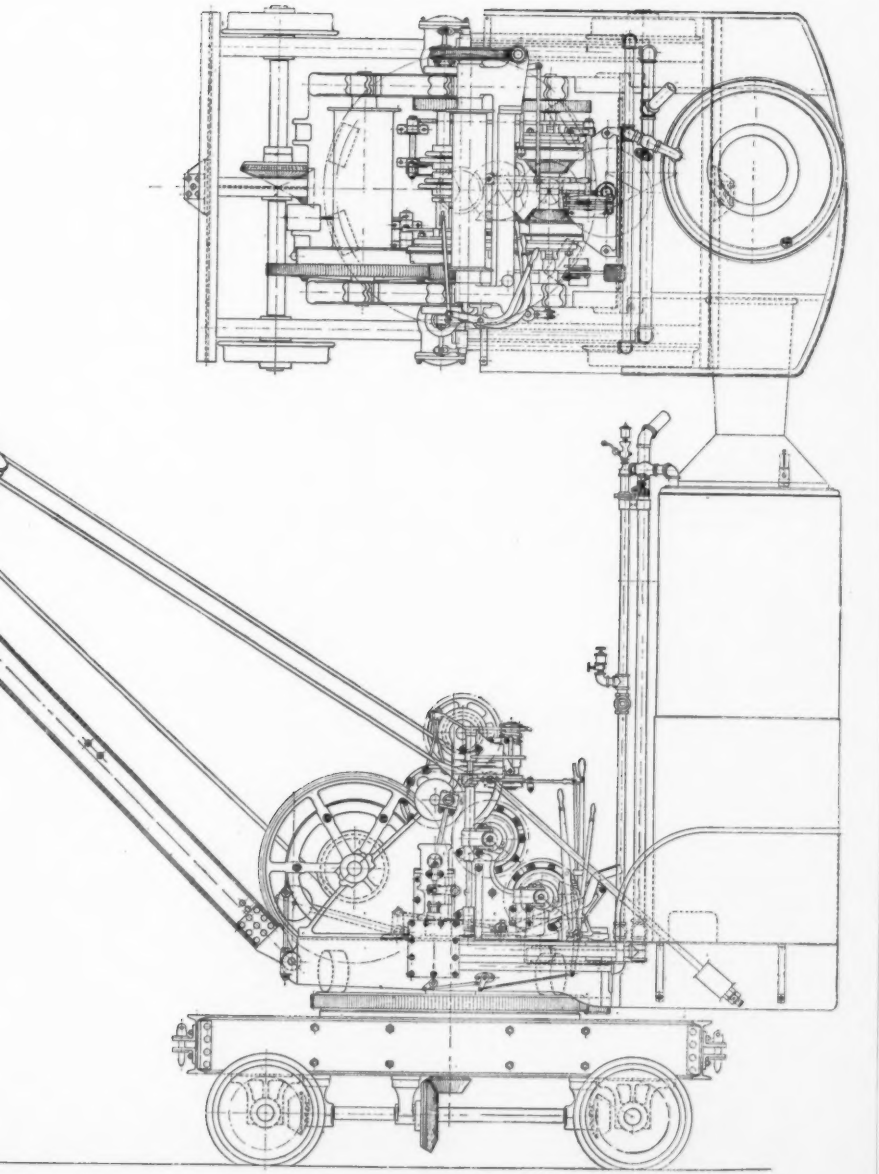
to different positions under the lever any desired amount of pressure can be obtained, thus enabling the clutch to be so used that more or less slipping shall occur during the period of acceleration, and until it is desired to lock the parts rigidly together. The wear produced by this slipping is borne by the wooden surfaces, which are so large that the wear is slight. Soft wood is found preferable because of its elasticity and lesser wear than hard wood, for which reason also the wood is used on its side, not on end. Each wooden ring is composed of a series of short segments, which any carpenter can quickly saw out of a smooth plank of proper thickness, and the construction admits of their easy removal and renewal. Experience has firmly established the admirable qualities of this clutch, especially for the severe conditions of use and exposure which obtain in the case of locomotive cranes. The boiler is of the vertical tubular type, possessing quickness in generating steam, economy in fuel and large steaming capacity. The platform under it is utilized as a water tank, the weight of which and of the boiler, serves largely to counterbalance the crane.

These cranes are further provided with clips whereby they may be clamped to the rails to give greater stability, if needed. European practice tends to depend largely on these clips, or on blocking, to provide the stability necessary to give the crane its full lifting capacity. The practice of the Yale & Towne Mfg. Co., however, is to provide sufficient counterbalance to make the crane self-supporting *in any position*, with its full load suspended at the normal radius.

As the advantages of the locomotive crane for handling materials have become more apparent to users, the element of "handiness" has become a greater requisite, and has led to important modifications in many of the details of construction. This type of crane has now passed the stage of development and has been so thoroughly reconstructed and Americanized as to adapt it admirably to a very wide range of uses. Its great value is only beginning to be appreciated, and will undoubtedly lead to its much larger adoption in the future. It is only when used continuously that its facilities of manipulation and capacity for rap-

Plate I.





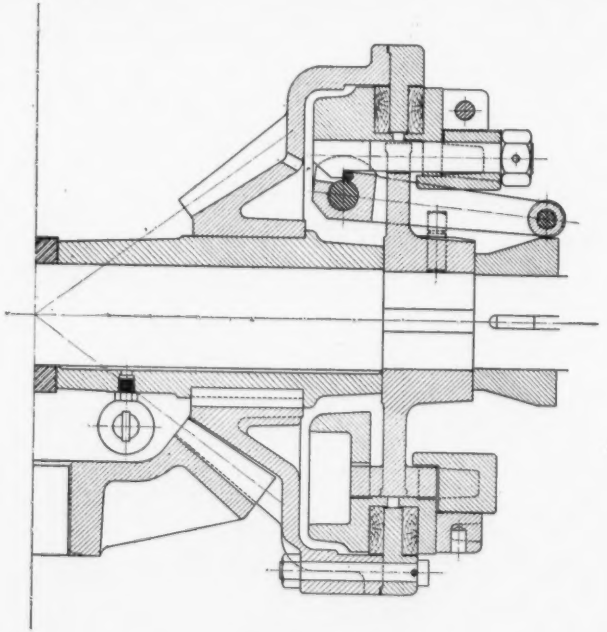


Plate II.

LOCOMOTIVE CRANE CLUTCH

THE YALE & TOWNE MANUFACTURING CO.

DR. 92 10682

idly performing a great amount of work are fully developed. Wherever it has been introduced under conditions which admit of the full development of its efficiency, it has proved unexpectedly useful and satisfactory, and has repeatedly effected an economy of time and labor so great as to enable the crane to thereby pay for itself within the space of twelve months or less. The field for its application is almost without limit, and it may confidently be predicted that American users will rapidly find opportunity for a steadily increasing use of the Locomotive Crane.

THE NEW THORNYCROFT BOILER.

The modified form of Thornycroft boiler, referred to on page 946, of volume V of the JOURNAL, possesses so many points of difference from the one which has become familiar during the past four or five years as to make it essentially a new type of water-tube boiler. The first of these boilers to be fitted in any vessel are in the British torpedo-boat destroyer *Daring*, which has three of them, and whose trials will take place at an early date. The description and the illustrations of the boiler are from "Engineering."

Fig. 1 is a front elevation; Fig. 2 a longitudinal elevation partly in section; Fig. 3 a cross section, and Fig. 4 a plan, one-half of which shows sections at different planes. In place, however, of there being two wing cylinders at the bottom and a separator or steam-collector cylinder at the top, as in the original Thornycroft boiler, this boiler has one large lower cylinder and two small supplementary wing pipes at the sides. The grate area, as will be seen, is disposed on each side of the lower cylinder, so that there are two furnaces to each boiler, in place of one furnace, as in the older design. The main part of the heating surface is supplied by the series of tubes that connect the top and bottom cylinders. For the sake, chiefly, of insulation, a series of curved tubes run from the top cylinder to the two large pipes placed in the wings. These tubes are placed close together, excepting where they are expanded into the top cylinder and connected to the wing pipes respectively, where the exigencies of construction compel them to be separated. Every alternate tube of this series has to be bent outwards, as shown in the cross-sectional illustration, and the spaces thus formed are stopped by fire tiles, as shown. It will be seen that these two outer series of tubes, being placed close together, form an insulating wall, by means of which the extreme heat of the furnace is prevented from attacking the smoke jacket or outer casing of the boiler, which

is formed of sheet iron, and is placed close up to the insulating row of tubes, as shown. It would appear at first sight that this row of small tubes would afford but little protection, but it will be evident on reflection that the temperature of the tubes will not rise higher than that due to the boiler pressure, unless steam be generated in the tubes and become superheated. The excellent circulation maintained in the Thornycroft boiler is, however, relied upon as sufficient to prevent any superheating. It will be seen by the sectional plan, Fig. 4, that the wing pipes are carried right round the back of the grate, and are attached to the bottom central cylinder by a flange.

The tubes, however, are not carried further than indicated in the plan, so that the back end of the boiler has to be insulated by fire tiles or other means. The attachment of the tubes to the wing pipes is made by union joints, the ends of the tubes being flanged, and being held by means of glands, into nipples tapped into the wing pipes, a soft washer being used to make each joint steam tight. In the upper cylinder or steam separator, the ends of the tubes are expanded in the usual way.

It will be remembered that a leading principle in the Thornycroft boiler is that the tubes which form the heating surface are so arranged that the spaces enclosed by them constitute flues for the passage of products of combustion to the chimney. The same feature is retained in the present type of boiler. Thus it will be seen, by reference to the illustrations, that the main series of tubes—which are placed on the inner side of each furnace—have their extreme rows so arranged that the tubes are touching, as in the single rows of insulating tubes. To effect this the tubes are bent at the ends, where they are expanded into the upper and lower cylinders. At the bottom and top, where the tubes join the cylinders, there are, therefore, triangular spaces. The products of combustion pass in through the triangular spaces at the bottom and ascend, circulating amongst the inner rows of tubes (which do not touch each other), and finally pass to the heart-shaped space in the middle of the boiler, which thus becomes a smoke chamber leading to the uptake at the back end of the boiler.

In designing his water-tube boilers Mr. Thornycroft has always kept prominently in view the necessity for ample circulation. In order to obtain this in the older design, the ends of the top and bottom cylinders were carried beyond the casing of the boiler and were then connected by large pipes, to which the name of "downcomers" has been given. No doubt in this way a very effectual means of circulation was set up, but a good deal of the structure was given up for no useful purpose so far as evaporation was concerned; indeed, it was cooling surface, which was an excellent thing from a circulation point of view, but not conducive to other efficiencies.

Mr. Thornycroft has made his new boiler so that the whole is contained within the smoke casing, and the downcomers, which are now several in number, are placed within the central smoke chamber connecting the top and bottom cylinders, as shown in the cross and longitudinal sections. By the latter it will be seen that these downcomers are curved in form. This is probably done for the purpose of allowing for expansion when heated. It may be found possible to make these pipes straight, if there be no other reason for bending them than the desire to allow for expansion and contraction.

An advantage claimed for this "flue-way" system of arranging the tubes supplying the heating surface is that the gases arising from the burning fuel are inclosed in a close combustion chamber, and in this way a nearer approach to complete combustion is obtained. In the present case the gases, as liberated from the coal, rise to the upper part of the space above the grate, together with the air blown through the fire by fans (when forced draft is used). The air and the gases in this way have a good opportunity of being thoroughly mixed whilst at the temperature necessary for combustion. Supposing a sufficient supply of air be maintained, the gases will not therefore be cooled down by contact with the surfaces of the tubes, before combustion is complete. It is also claimed that the "flue-way" system has the advantage of keeping the heated gases longer in contact with the heating surface of the tubes. It may be mentioned, in connection with this point, that in the Lagrafel-d'Al-

lest boiler fire tiles were arranged so as to secure this advantage. It will be evident, however, that on general principles it is desirable to keep the heated gases in contact with the heating surface for a sufficient length of time to allow the heat to be transferred to the water to be evaporated.

An advantage claimed for bent tubes, as in this type of boiler, as compared with the straight-tube arrangement, is that greater heating surface is obtained within given dimensions of space and also that a lighter boiler is produced, other things being equal. In water-tube boilers of this type, the tubes practically supply all the heating surface. The large cylinders used, however, form a very appreciable addition to the total weight, and it is evident that the smaller the proportion of weight contained in the cylinders the more effective the boiler will be for its weight, if other considerations are equal.

With this new design, which may be distinguished as the *Daring* type of boiler, Messrs. Thornycroft state they get a more compact arrangement, so far as fitting the boat is concerned, and the advantage of the double furnace gives a boiler with a manageable size of grate and large heating surface. This is shown by the fact that the *Daring* has but three boilers, whilst it would have required six of the older type, such as is used in the *Speedy;* which vessel, it will be remembered, had eight boilers, her engines developing over 4,500 horse power.

In regard to the circulation question, to which reference has already been made, it is well to remember that not only has the protection of the tubes from the fire to be provided for by circulation, but also the question of deposit in the tubes arises. In this respect, the modern designer of water-tube boilers stands on a very different footing from his predecessors of ten or a dozen years ago. The great improvement made in evaporators and distillers, and—more important still—the recognition that it is an essential feature of good practice that these should be carried, makes the incrustation trouble very much lighter. The chief difficulty appears to be that which arises from grease which comes over with the feed.

In the *Daring* it is probable that, as in the case of torpedo boats, oil will not be used in the cylinders; but experience with the old type of Thornycroft boiler showed that a certain amount of solid matter was usually found deposited in the bottom or wing cylinders, and that the greater part of this plastic mass is combustible.

It is possible that even this trouble will be got over by the use of a grease arrester, in the design of which there appears a probability that success has been reached. At times, however, salt water may be expected to find its way into the boiler. A leaky condenser will speedily flood the boilers with salt water, as was proved on a recent trial trip, or it may be necessary to use salt water for make up through failure of the evaporators. Such an accident occurred to some torpedo boats built for a South American navy by Messrs. Thornycroft, and containing the Thornycroft water-tube boiler. In this case the boats were run for a considerable time on salt water, but arrived at their destination apparently in good order, and have been in work since.

In some forms of water-tube boiler lime is inserted in the feed, and care is taken to heat the water to the point of ebullition before it is brought into contact with the heating surface of the boiler. In this way the lime salts, together with the grease, are said to combine with the added lime, which is deposited in the form of mud and not of scale. By using such precautions it is said salt water can be used for make-up, care, of course, being taken that the saturation is not too high. Messrs. Thornycroft, however, state that the fairly extended experience they have had with their boiler indicates that such precautions are not necessary, but at the same time they do not advocate salt water being introduced into the boiler.

The new type of Thornycroft boiler possesses to a greater degree than the older design the advantage of a lofty furnace. The difficulty in stoking long grates consists largely of the fact that in cylindrical furnaces of the ordinary boiler the coal cannot be thrown up. To borrow a term from artillerists, the trajectory is too flat, so that high velocity is required. In the trials of the *Speedy* the Sheerness stokers expressed themselves delighted

Fig.1

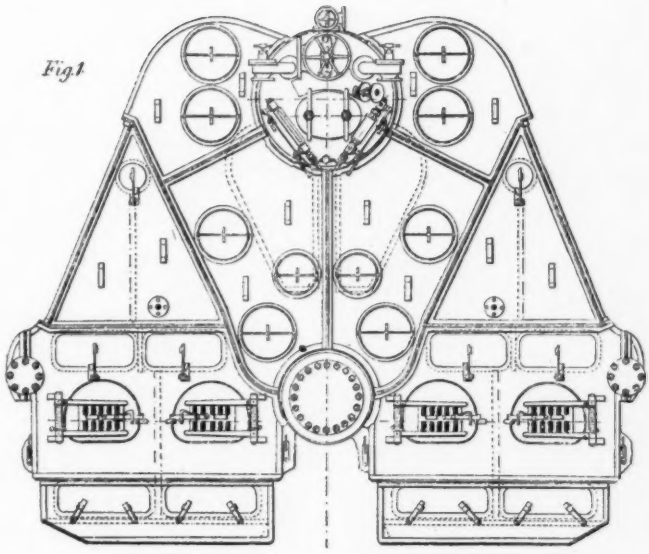


Fig. 2

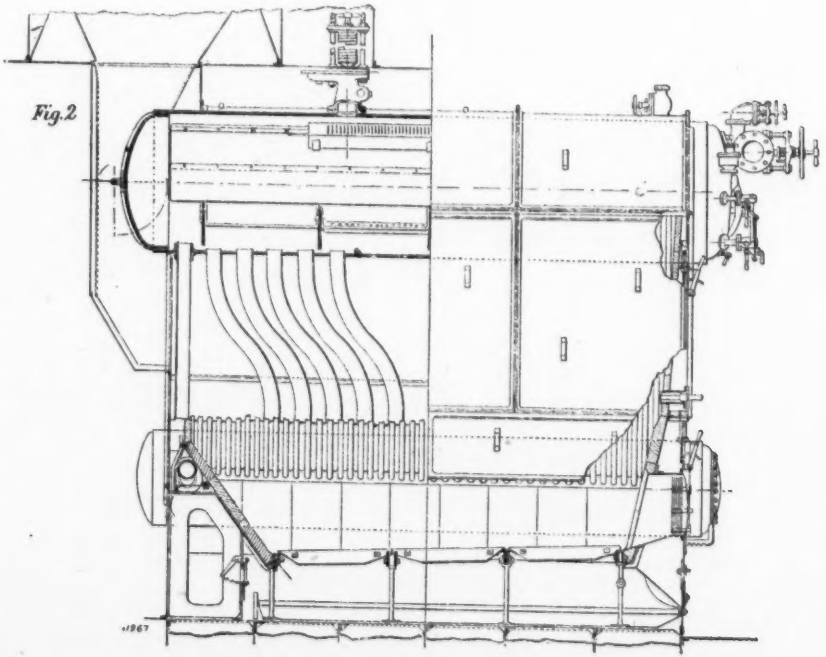


Fig.3

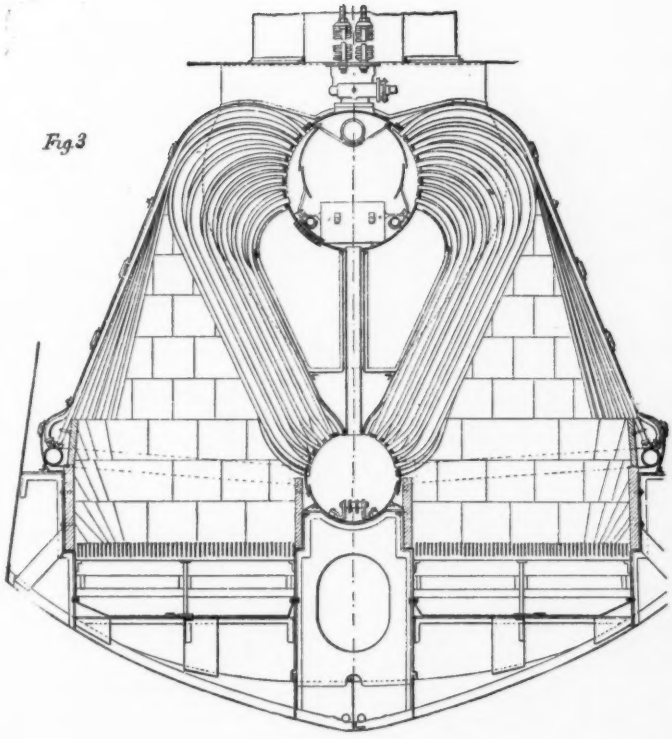
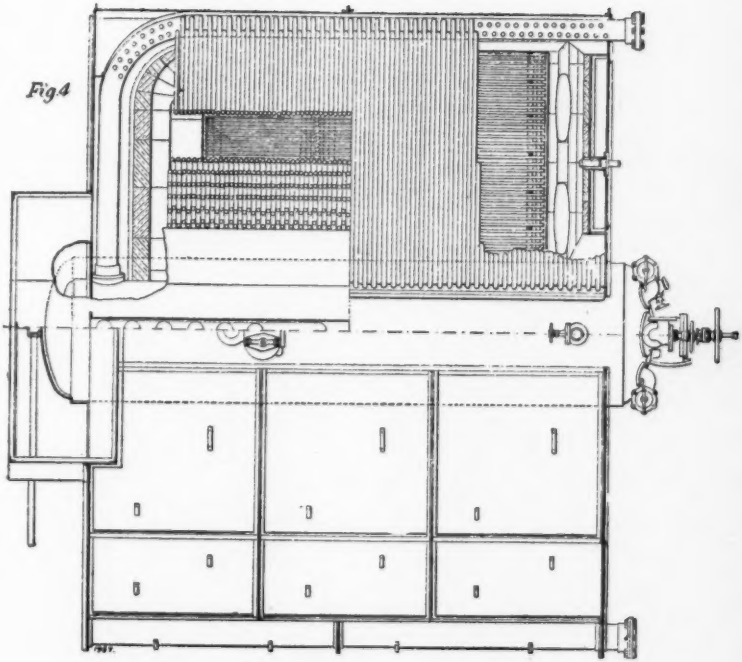


Fig 4



with the ease with which coal could be got all over the furnace, and in the new design this advantage will be still more apparent.

This new type of boiler is also extremely well adapted to being grouped. In such cases the single rows of tubes are naturally only required on the outside boilers. Another point worthy of notice is that the design of this boiler can be easily accommodated so that it can be placed low down in the run of a vessel where the bottom fines. By raising the wing pipes a little the lower corners can be cut off practically without sacrificing heating surface.

On the whole, the boilers of the *Daring* are a most interesting addition to the great marine engineering feature of the hour, viz: the evolution of a trustworthy water-tube boiler. The trials of the vessel will be watched with much interest.

COMPARISON OF TYPICAL OCEAN STEAMERS.

By J. M. Lincoln, Associate.

The accompanying table has been prepared with a view of placing in convenient form the principal data available on typical ocean steamers. The sources from which it has been compiled are various engineering and trade publications, and transactions of technical societies, and as far as it goes, I believe it is reliable. There are, necessarily, many data which cannot be obtained for all the steamers, but I think this point will be appreciated by any one who may have endeavored to get complete data on a merchant steamer and her performance.

The coal consumption is, of course, almost impossible of getting accurately, or if that is given correctly, the I.H.P. corresponding is not always reliable, so that the figures for that must, in many cases, be accepted with considerable reserve.

The object attempted has been to put the most reliable data in such shape that it can be conveniently used.

Steamer.	Type.	Builder.	When Built.	Owner.	Hull.				Tons.		
					Extreme Length.	Load Water Line.	Beam.	Depth from main deck.	Gross.	Under decks.	Net.
Arizona	S. S.	Fairfield Co.	1879	Guion Line	464	450.2	45.2	35.7	5,164	5,007	2,657
Aurania	S. S.	Thompson	1883	Cunard Line	.....	470	57.2	37.2	7,269	4,040	3,468
America	S. S.	Thompson	1884	National Line	459	432	51.3	38.6	5,528	5,138	2,834
Alaska	S. S.	Fairfield	1881	Guion Line	.....	500	50	38	6,932	6,586	3,554
Aller	S. S.	Fairfield	1885	N. G. Lloyd	.....	438	48.1	34.6	4,964	4,806	2,924
Augusta Victoria	T. S.	Vulcan Co.	1889	Hamburg Line	480	459.3	55.7	28.1	7,661	4,275	3,893
Britannic	S. S.	Harland & Wolff	1874	White Star	468	455	45.2	33.7	5,004	4,757	3,152
Columbia	T. S.	Laird	1889	Hamburg Line	480	463.5	56.0	35.5	7,363	5,915	3,737
Campania	T. S.	Fairfield	1893	Cunard Line	622	600	65.3	41.6	12,950	10,267	.....
City of Rome	S. S.	Barrow	1881	Anchor Line	610	546.2	52	37	8,144	7,468	3,453
City of Paris	T. S.	Thompson	1888	Inman Line	560	527.6	63 2	39.2	10,499	8,570	5,739
City of Berlin	S. S.	Caird	1874	Inman Line	510.6	488 6	44.2	34.9	5,526	5,151	3,302
Elbe	S. S.	Fairfield	1881	N. G. Lloyd	.....	418 2	44.9	35.4	4,510	2,810	2,810
Ems	S. S.	Fairfield	1884	N. G. Lloyd	450	429 8	47	34.5	5,192	.....	2,954
Eider	S. S.	Fairfield	1883	N. G. Lloyd	450	429 8	47	34.5	5,192	4,623	2,894
Empress of India	T. S.	Barrow	1890	Canadian Pacific R. R.	485	455.6	51.2	36	5,905	5,098	3,003
Furnessia	S. S.	Barrow	1880	Anchor Line	.....	445.1	44.6	34.5	5,495	5,038	3,613
Fürst Bismarck	T. S.	Vulcan Co.	1891	Hamburg Line	520	502.6	57.6	38	8,874	.....	4,463
Gallia	S. S.	Thompson	1879	Cunard Line	450	430.1	44.6	34.4	4,809	4,753	2,898
Great Eastern	Sc. and Pad.	Scott-Russell	1857		692	679.5	82.6	58.	18,915	18,837	.....
Kaiser Wilhelm II	S. S.	Vulcan Co.	1889	N. G. Lloyd	.....	449.6	51	35.6	6,970	.....	4,773
Lahn	S. S.	Fairfield	1887	N. G. Lloyd	465	448.4	49	34 9	5,681	.....	2,879
La Bourgogne	S. S.	Charges & C., France	1885	French Line	494.5	480	52.3	34.4	7,395	.....	2,985
La Touraine	T. S.	Charges & C., France	1890	French Line	538.9	517.7	56.3	34.6	7,121	.....	.....
La Normandie	S. S.	Barrow	1882	French Line	.....	459.3	50	37.4	6,283	.....	2,687
Normannia	T. S.	Fairfield	1890	Hamburg Line	520	500	57.5	34	8,716	6,550	3,750
Orient	S. S.	Fairfield	1879	Orient S. N. Co.	460	445 6	46.3	35 1	5,365	5,118	3,281
Oregon	S. S.	Fairfield	1883	Cunard Line	520	501	54.2	39	7,500	7,375	.....
Ormuz	S. S.	Fairfield	1886	Orient S. N. Co.	.....	465.5	52.1	34	6,031	5,663	2,940
Oroya	S. S.	Barrow	1886	Pacific S. N. Co	.....	460	49.3	35.3	6,059	5,688	3,266
Ophir	T. S.	Napier	1891	Orient S. N. Co.	482	469	53.6	37	6,910	.....	3,222
Pembroke Castle	S. S.	Barrow	1883	Donald, Currie & Co.	.....	400.2	42.6	21.4	3,878	3,639	2,521
Stirling Castle	S. S.	Fairfield	1882	Italian Flag	430	418.6	50	30.8	4,916	4,111	2,419
Servia	S. S.	Thompson	1881	Cunard Line	530	515	52.1	37	7,392	7,212	3,971
Scotia	Side Wheel.		1862	Cunard Line	.....	369	47.6	30.6	4,667	4,660	2,931
Scot	T. S.	Denny Bros.	1891	Union S. S. Co.	502	460	54.6	37.6	6,500	.....	.....
Spree	S. S.	Vulcan Co.	1890	N. G. Lloyd	485	463	52	34	6,963	.....	3,769
Teutonic	T. S.	Harland & Wolff	1889	White Star	582	565.8	57.8	39.2	9,686	8,829	4,245
Umbria	S. S.	Fairfield	1884	Cunard Line	.....	501.6	57.2	38.2	8,128	7,129	3,699
Werra	S. S.	Fairfield	1882	N. G. Lloyd	450	433.1	49.5	35.8	5 109	4,596	2,936

T. S.=Twin Screw. S. S.=Single Screw.

COMPARISON OF TYPICAL OCEAN STEAMERS, BY VAR

Net.	Displacement: At load Draught of	Displacement: Tons.	Area immersed midship section.	Block coefficient.	Midship section coefficient.	$\frac{D^{\frac{2}{3}} \times S}{T.H.P.}$	$\frac{D^{\frac{2}{3}} \times S^{3}}{I.H.P. \times \sqrt{\frac{Entrance}{10}}}$	Kirk's analysis: Length of forebody.	Kirk's analysis: Angle of entrance.	Indicated horse power.	Speed in knots.	Eng: Type.	Cylinders: High pressure.	Cylinders: Intermediate.	Cylinders: Low pressure.	Cylinders: Stroke.	Revolutions per minute.
	ft. in.								° ′								
2,657	18 9	6,415	758	.589	.895	269.2	217	153.79	7 30	6,300	17.	Compound....	1-62	.....	2-90	66	55
3,468	20 0	8,800	1,020	.575	.942	266	204.6	170.	8 38	8,500	17.5*	Compound....	1-68	.....	2-91	72	.....
2,834	26 0	9,550	1,275	.570	.935	345	265	169.3	8 32	7,354	17.8*	Compound....	1-63	.....	2-91	66	70
3,554	21 0	9,210	949	.614	.904	245	.....	160.23	8 2	10,500	18.	Compound....	1-68	.....	2-100	72	.....
2,924	21 0	7,447	907	.590	.899	277	225	150.6	8 10	11,000	18.5	Triple.....	44	70	100	72	.....
3,893	22 9	9,500	.....	.572	.....	195	.....	.....	.....	7,974	17.9	Triple.....	2-41	2-67	2-106	63	78
3,152	23 6	8,500	926	.616	873	289.3	.....	129.	17 6	14,100	18.31	Triple.....	2-41	2-67	2-106	63	78
3,737	22 9	9,500	.....	.55	.....	.....	.....	.....	.....	4,900	16.	Compound....	2-48	.....	2-83	60	.....
	24 0	10,000				225				13,680	19.15	Triple.....	2-41	2-66	2-101	66	74
.....	25 0	18,000	.....	.....	.....	227.8	.....	.....	.....	30,150	23.18	Triple.....	4-37	2-79	4-98	69	84
3,453	26 0	13,500	.....	.....	.....	.....	.....	161.27	8 29	11,890	18.23	Compound....	3-46	.....	3-86	72	56
	21 5½	11,230	1,031	.649	.925	255	201.3										
5,739	23 0	13,300	.....	.603	.....	278	.....	.....	.....	20,625	21.8	Triple.....	2-45	2-71	2-113	60	90
3,302	.....	.....	.....	.....	.....	.....	.....	.....	.....	6,025	.....	Triple.....	41	65	101	66	.....
2,810	20 0	6,350	807	.591	.901	275.5	229	144.6	7 56	5,665	16.5	Compound....	1-60	.....	2-85	60	66
2,954	20 7½	7,030	877	.593	.907	273	223	149 4	8 40	7,251	17 5	Compound	1-62	.....	2-86	60	.....
2,894	.....	7,405	877	..	.....	.....	.....	.....	.....	6,970	17 5	Compound....	1-62	.....	2-86	60	66
3,003	22 6	.....	.....	.....	.....	.....	.....	.....	.....	10,685	19.	Triple.....	2-32	2-51	2-82	54	89.5
3,613	22 2½	8,578	893	.682	.903	284	273	108.7	10 28	4,045	14.	Triple.....	37	62	100	66	.....
4,463	22 6	10,200	.....	.....	.....	.....	.....	.....	.....	16,412	20.7	Triple.....	2-43½	2-67	2-106½	63	.....
	26 0	12,960				254											
2,898	18 5	6,125	.....	.615	.....	.....	.....	.....	.....	5,261	15.7	Compound....	1-64	.....	2-80	75	.....
	25 0	8,600															
.....	30 0	30,000	.....	.....	.....	.....	.....	.....	.....	8,500	14.5	Simple	.....	.....	4-74	168	25
	25 6	27,000				359									4-84	48	55
4,773	23 0	.....	.....	.....	.....	.....	.....	.....	.....	6,500	16.4	Triple.....	41½	67	106½	63	70.5
2,879	22 0	7,700	.....	.....	.....	252	.....	.....	.....	8,700	17.78	Triple.....	2-32½	68	2-85	72	70
2,985	24 0	9,925	.....	.... .	.....	.....	.....	.....	.....	7,200	19.03	Compound....	3-43	.....	3-90	67	.....
.....	23 4½	11,685	.....	.....	.....	.....	.....	.....	.....	9,500	18.75	Triple.....	2-41	2-60⅝	2-100	65⅝	73
										12,000	20.00						78
2,687	24 3	.....	1,060	.....	.....	.....	.....	.....	.....	.....	.....	Compound...	3-35 7/8	.....	3-74⅞	67	.....
3,750	19 9⅜	7,075	892	.614	.901	265	219.5	146.41	8 44	6,959	16.66						
3,281	24 0	11,500	.....	.....	.....	266	.....	.....	.....	16,352	20.78	Triple.....	2-40	2-67	2-106	66	85
	26 0	9,500	1,094	.....	.....	.....	.....			.....	.....						
.....	21 4½	7,770	904	.621	.919	270.8	225	144.17	8 21	5,433	15.53	Compound....	1-60	.....	2-85	60	60
2,940	23 8	11,000	1,150	.599	.849	227.9	190	164.3	9 39	13,300	18.3	Compound....	1-70	.....	2-104	72	62
3,266	.....	.....	.....	.....	.....	.....	.....	.....	.....	9,000	.....	Triple.....	46	73	112	72	.....
3,222	22 7	8,840	.....	.....	.....	.....	.....	.....	.....	6,751	.....	Triple..	40	66	100	72	64.5
2,521	24 6	10,600	.....	.603	.....	279	.....	.....	.....	11,400	18.75	Triple.....	34	51½	85	54	102
2,419	17 0	5,130	643	.623	.900	284	258	122.9	8 49	2,436	13.25	Compound....	1-43	.....	2-86	57	.....
3,971	22 3	7,600	990	.569	.889	286.8	233.7	151.3	8 23	8,396	18.4	Compound....	1-62	.....	2-90	66	66.5
2,931	23 3	10,960	1,046	.610	.862	231	192	145.3	10 42	8,141	16.9*	Compound ..	1-72	.....	2-100	78	.....
	25 2	12,450		.646	.....	.....	.....	.....	.....	10,300	17.						
.....	19 9	6,000	867	.605	.92	208.9	186	126.8	13 21	4,632	14.3*	Side lever.....	.....	.....	2-100	144	.....
3,769	23 0	10,000	.....	.....	.....	.....	.....	.....	.....	11,656	19 26	Triple.....	2-34½	2-57½	2-92	60	80
	22 0	8,900	.....	.....	.....	249	.....	.....	.....	13,000	19.6	Triple.....	2-37.4	1-74.8	2-98.4	70.8	78
4,245	22 0	12,000	.....	.....	.....	245	.....	.....	.....	19,500	21.0	Triple.....	2-43	2-68	2-110	60	78
3,699	22 6	9,860	1,090	.538	.896	263 8	191.8	184.	8 36	14,321	20,18	Compound....	1-71	.....	2-105	72	70
2,936	.....	.....	.....	.....	.....	.....	.....	.....	.....	6,474	17.6	Compound....	1-62	.....	2-86	60	68

* Voyage.

BY VARIOUS BUILDERS.—COMPILED BY J. M. LINCOLN.

Engine.						Propellers.								
...ers.														
Low pressure.	Stroke.	Revolutions per minute.	Piston speed.	Cylinder ratios.	Cooling surface.	Number.	Number of blades.	Diameter.	Pitch.	Blade area.	Disk area.	Number.	Diameter.	
								Ft. in.	*Ft. in.*	*Sq. ft.*	*Sq. ft.*		*Ft. In.*	
2-90	66	55	605	1 to 4.21	12,540	1	4	23 0	33 0	.....	415.	9 {6 3	13 6	
2-91	72	.....	.....	1 to 3.6	.....	1	4	.....	.....	.....	.....	.....	.....	
2-91	66	70	770	1 to 4.3	.....	1	4	22 0	29 0	164	380.13	7 {1 6	15 0 14 0	
2-100	72	.....	.....	1 to 4.32	.....	1	4	23 0	34 6	.....	415.	9	15 0	
100	72	.....	.....	2 to 1, 2.53; 3 to 2, 2.04; 3 to 1, 5.16....	12,020	1	4	22 0	30 6	150	.....	6	.....	
2-106	63	78	819	2 to 1, 2.03; 3 to 2, 3.25; 3 to 1, 5.09....	.....	2	3	18 0	32 0	96	2.. 509.	8	15 1	
2-83	60	.....	.....	1 to 3.72	.....	1	4	23 6	31 6	.....	433.73	8	.....	
2-101	66	74	814	2 to 1, 2.25; 3 to 2, 2.86; 3 to 1, 6.37....	.....	2	3	18 0	31 0	96	2...509.	9	15 4	
4-98	69	84	966	2 to 1, 2.28; 3 to 2, 3.07; 3 to 1, 7.01....	.....	2	3	.....	.....	.....	.....	14 {12 1 1	18 18 10	
3-86	72	56	672	1 to 4	17,000	1	4	24 0	{33 to 38	.....	452.39	12 {8 4	14 4 14	
2-113	60	90	900	2 to 1, 2.49; 3 to 2, 2.53; 3 to 1, 6.3.....	.....	2	3	19 6	28 0	.....	2...597.28	9	15 6	
101	66	.....	.....	2 to 1, 2.09; 3 to 2, 2.49; 3 to 1, 5.03..	.....	1	4	21 6	31 6	150	363.05	8	.....	
2-85	60	66	660	1 to 3.9	.....	1	4	21 9	29 0	126	.....	4	15 6	
2-86	60	.....	.....	1 to 3.84	.....	1	4	.....	.....	.....	.....	.....	.....	
2-86	60	66	660	1 to 3.84	.....	1	4	22 0	32 0	.....	380.13	6	13 10	
2-82	54	89.5	805.5	2 to 1, 2.54; 3 to 2, 2.58; 3 to 1, 6.56....	.....	2	...	16 6	23 0	.....	.....	4	16	
100	66	.....	.....	2 to 1, 2.9; 3 to 2, 3.26; 3 to 1, 7.3	.....	1	4	.....	.....	.....	.....	.....	.....	
2-106½	63	.....	.....	2 to 1, 2.39; 3 to 2, 2.54; 3 to 1, 6.07....	10,800	2	3	19 0	27 11	86	2 ...567.	9	15 7	
2-80	75	.....	.....	1 to 3.22	8,300	1	4	21 0	29 6	.....	.....	8	14 6	
{4-74	168	25	700	}	.....	{1 sc.	4	24 0	44 0	}	.....	.....	10	} {17½ w.	}
{4-84	48	55	440	}	.....	{2 pad.	...	56 0	.....	}	.....	.....	} {14 h.	}
106½	63	70.5	740½	2 to 1, 2.62; 3 to 2, 2.51; 3 to 1, 6.52....	9,880	1	4	21 10	25 3	142.5	346.36	6	13 1½	
2-85	72	70	840	2 to 1, 2.12; 3 to 2, 3.2; 3 to 1, 6.84....	14,000	1	4	22 3	30 0	160.	.....	1 aux. {6 2	14 4 14 4	
3-90	67	.....	.....	1 to 4.81	.....	1	4	21 0	.....	.....	346.36	12	.....	
2-100	65⅝	{72 78	784 850	} 2 to 1, 2.21; 3 to 2, 2.68; 3 to 1, 5.9.....	22,455	2	3	19 8½	29 6	.....	2...610.12	9 {6 3	14 9½ 14 9½	
3-74½	67	.....	.....	1 to 4.55	11,682	1	4	22 0	31 6	.....	380.13	8 {4 4	13 9	
2-106	66	85	935	2 to 1, 2.8; 3 to 2, 2.5; 3 to 1, 7.0.....	.....	2	3	18 1½	26 9	.....	.....	9	16	
2-85	60	60	600	1 to 4.9	12,000	1	4	22 0	30 0	.....	380.13	4	15 6	
2-104	72	62	744	1 to 4.5	.....	1	4	.....	.....	.....	.....	9	16 6	
112	72	.....	.....	2 to 1, 2.51; 3 to 2, 2.35; 3 to 1, 5.93....	.....	1	4	.....	29 3	.....	.....	6	15	
100	72	64.5	774	2 to 1, 2.72; 3 to 2, 2.29; 3 to 1, 6.24....	11,546	1	4	22 0	28 6	149.6	380.13	6	13 6	
85	54	102	918	2 to 1, 2.28; 3 to 2, 2.72; 3 to 1, 6.14....	.....	2	3	17 0	23 3	.....	2...453.96	7 {6 1	{15 1 15 1	
2-86	57	.....	.....	1 to 4.0	.....	1	4	.....	.....	.....	.....	.....	.....	
2-90	66	66.5	731.5	1 to 3.9	.. ...	1	4	22 4	31 0	.....	391.74	.....	.....	
2-100	78	.....	.....	1 to 3.85	15,000	1	4	.....	.....	.....	.....	.....	.....	
2-100	144	.....	.....	.....	.....	1	4	.....	.....	.....	...	.....	.....	
2-92	60	80	800	2 to 1, 2.77; 3 to 2, 2.56; 3 to 1, 7.0.....	.....	2	3	17 5	25 0	.....	2...476.48	6	15 3	
2-98.4	70.8	70	826	2 to 1, 2.04; 3 to 2, 3.45; 3 to 1, 6.99....	18,945	1	4	21 7	29 0	139	365.87	10 {6 4	15 4 15 4	
2-110	60	78	780	2 to 1, 2.5; 3 to 2, 2.61; 3 to 1, 6.52.....	.....	2	3	19 6	28 6	108	2...597.28	16 {8 4 4	12 6 12 12 6	
2-105	72	70	840	1 to 4.39	.....	1	4	24 6	33 6	.....	471.	9	16 6	
2-86	60	68	680	1 to 3.7	.....	1	4	22 0	30 0	.....	380 13	5 {1 4	} 16	

Boilers.										Coal.		Ratios.							
	Length.		Number of furnaces each.	Total number of furnaces	Thickness of shell.	Total Grate.	Heating surface.	Ratio heating to grate area.	Steam pressure.	Per day.	Per I.H.P.	I.H.P.—Per ton gross.	I.H.P.—Per ton of displacement.	I.H.P.—Per square foot grate.	I.H.P.—Per square foot ⌀.	I.H.P.—Per square foot of draught X beam at ⌀.	Area of draught X beam at ⌀.	Length / Beam.	Length / Depth.
In.	*Ft.*	*In.*			*In.*	*Sq. ft.*	*Sq. ft.*		*Lbs.*	*Tons.*									
6	17	6	6	.....	$\frac{11}{16}$	780	19,500	25	90	125	1.87	1.2	.98	8.07	8.31	6.3	994	9.95	12.89
	.....		.....	.....	.....	1,001	23,984	23 2	90	215	2.2	1.16	.96	8.48	8.33	8.1	1044	8.95	12.03
o	11																		
o	17		.....	.....	$\frac{13}{16}$	882	22,750	23.8	95	195	2.53	1.13	81	8.13	5.89	5.38	1334	8.47	11.52
o	.....		.....	54	.....	1,242	.....	.....	100	253	2.14	1.73	1.19	9.	12.1	10.	1100	10.00	12.6
	.....		6	36	.....	799	22,630	28.3	150	152	1.78	1.6	1.06	9.98	8.79	7.9	1010	9.12	12 66
1	19	8	6	48	$1\frac{1}{16}$	1,120	35,955	32.1	150	.....	.....	1 84	1.47	11.5	.....	6.24	1276	8.28	11.79
	.....		.....	32	.....	465	19,500	41.5	75	110	2.09	1.09	.64	10.19	5 99	5.18	1062	10.11	12.64
4	17	2	6	54	$1\frac{13}{16}$	1,216	35,000	28.7	150	288	.....	1.85	1.36	11.2	.....	10.25	1334	8.33	11.86
	17		8	.....	.....	.....	.....	.....	.....	484	1.5	.....	.....	.....	.....	.....	.....	.....	.....
	11	6	4	102	.....	2,500	.....	.....	165	646	2.0	2.41	1.67	12.06	.....	18.4	1632	9.23	14.45
	10	o	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	19	o	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	.....		3	60	$1\frac{1}{4}$	1,398	29,286	21 05	90	185	2.2	1.46	.807	11 00	11.5	8.75	1360	10.43	14.00
	19	o	6	54	$1\frac{5}{16}$	F 1,026 / N 1,273	50,265	F 48.9 / N 39 5	150	328	1.52	1.9	1.55	F. 20.1 / N. 16.2	.....	12 83	1453	8.37	12.69
	.....		.....	24	.....	324	14,616	43 5	150	.....	.....	1.09	.....	18.6	.....	.....	.....	.....	.....
	17	3	6	24	$1\frac{1}{8}$	624	15,800	25.34	80	116	1.91	1.25	.89	9.08	7.02	6.3	898	9 4	12.0
	.....		.....	.....	.....	780	19,700	25.1	100	.....	.....	1.41	1.03	9.3	8.27	7.4	978	9.38	12 47
o	16	6	6	36	.....	780	19,700	25.1	95	.....	.....	1.14	.94	8 93	7.8	.....	.....	.....	.....
	19	o	8	32	$1\frac{1}{8}$	.....	.....	.....	160	130	1.59	1.9	.....	.....	.....	9.27	1152	.....	.....
	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	1.35	.47	.....	4.7	.....	.....	.....	.....
7	19	o	8	72	$1\frac{1}{32}$	1,453	47,000	32.4	157	287	1.63	1.8	1.26	11.2	.....	10.9	1498	8.77	13.22
6	9	6	3	24	$\frac{17}{32}$	538	13,000	24.1	75	100	1.9	1.07	.....	9.79	.....	.....	11.12	964	12.5
	18		.....	112	.....	.....	Sc. 30,000 / Pad 19,200	.....	25	Sc. 180 / P. 120	3.0 / 3.5	.....	.....	.....	.....	.....	2475 / 2104	8.19	11.83
	17	4	4	24	$1\frac{13}{32}$	588	18,090	30.8	157	120	1.72	.....	.....	11.00	.....	4.49	1173	8.81	.....
4	18	9	6																
4	9	6	3	42	.....	874	25,414	29.1	150	170	1.82	1.69	1.23	9.95	.....	8.4	1124	9.74	12.74
	.....		.....	.....	.....	830	24,918	28.9	85	150	1.69	1.21	.905	8.67	.....	6.9	1295	9.47	14.34
9½	20	4½	6																
9½	10	6½	3	45	.....	1,162½	33,617	28.8	150	260	2.00	1.69	1.039	10.4	.....	9 22	1312	9.2	14.9
9	18	6	6																
	.....		3	36	.....	756	21,404	28 37	85.2	148	2 00	1 1	.87	8.6	6.5	5 9	1195	8.81	11.68
	17	6	8	72	$1\frac{7}{16}$	1,453	46,490	31.1	160	306	1 75	1.37	1.47	10.5	.....	11.1	13.80	873	13.15
6	17	6	6	24	.....	620	15,820	25.5	75	.....	....	1.01	.55	9.43	4.99	4.51	1204	9.68	12.71
5	16	9	8	72	.....	1,428	38,047	26.6	110	320	2.2	1.77	1 21	9 3	11 56	10 4	1274	9 259	12.5
	.....		6	36	.....	850	26,000	30.6	150	.....	....	1.5	.....	10.59	.....	.....	.....	8 93	13.5
6	18	o	6	36	.....	627	17,640	26.5	160	.....	.....	1.11	.76	10.79	.....	5.34	1264	9.38	13.03
1	19	8	6							weighed									
1	10	o	3	39	$1\frac{1}{32}$	756	26,004	34.3	160	†110	.....	1.63	1.08	15 08	.....	8.68	1313	8.79	12.69
	.....		.....	.....	.....	288	7,896	27.5	90	44	1.7	.63	.47	8.49	3.76	3.36	724	9.4	18 7
	.....		.....	.....	.....	787	21,161	26 9	100	.....	.....	1.7	1.1	10.6	8.48	7 54	1113	8.4	13 63
	.....		.....	.....	.....	1,014	27,483	27.1	90	205	2.0	1.28	.94	10.15	9.84	8 9	1159	9.9	12.72
	.....		.....	.....	.....	.....	.....	.....	.....	168	3.4	.99	1.29	.....	5.34	.....	.....	775	12.06
3	18	o	6	36	$1\frac{3}{16}$	837	22,964	24.4	170	.....	.....	.....	1.16	13.8	.....	9.46	1953	9.	12.34
4	18	7	6																
4	10	3	3	48	$1\frac{1}{8}$	1,120	36,964	33.0	170	230	1 65	1 89	1.46	11.6	.....	11.2	1144	9.	12.34
6	17	o	6																
	17	o	4	76	.....	1,163	40,072	34.4	180	325	1.6	1.75	1.23	14.6	.....	13 3	1271	5.82	14 55
6	10	o	3																
6	18	o	8	72	.....	1,638	38,823	23.1	110	330	2.1	1.85	1.45	8.5	13.14	11.6	1283	8.77	12.5
	17	9	3 / 6	27	.....	.....	17,500	.....	.....	120	1.73	1.26	.....	.....	.....	.....	.....	9.4	12.9

† For 16 knots.

NOTES.

TEST OF A YARROW BOILER.

The "London Times" of November 22, 1893, contains an account of a test of one of the water-tube boilers intended for H.M.S. torpedo-boat destroyer *Hornet*, a sister to the *Havock*. The type of boiler was described and illustrated on Page 947, of Volume V, of the JOURNAL, and the one tested had a grate 6½ feet long, 20.6 square feet of grate surface, and 1,027 square feet of heating surface. The following is the account of the test:

To test the boiler under the worst conditions of working, it was placed in the open without shelter and exposed to the fog which prevailed on the day of trial. In the presence of several engineering experts who were in attendance, the boiler, filled to its proper working height with cold water of the temperature of the surrounding air, had its fire lit at 2·20 P. M.; at at 2·30 P. M. the steam gauge pointer began to move, at 2·36 P. M., the gauge showed 60 lbs. pressure of steam, at 2·40 P. M., 100 lbs.; and at 2·42 P. M. a pressure of 180 lbs. per square inch was registered. The boiler not being within any enclosed space, to produce the same effect on the fire as obtains in the application of forced draft on shipboard a steam blast, as in an ordinary locomotive, was applied in the funnel. This was put on at 2·40 P. M., when the gauge indicated 100 lbs. pressure, so that in two minutes after its application the pressure increased 80 lbs. per square inch. The blast being under entire control, the air pressure used could be ascertained with exactness, and from readings of the gauge did not exceed 3½ in. From 2·42 P. M.—two minutes after putting on the blast—until the conclusion of the trial, at about 3·20 P. M., steam was maintained and was blowing off at the full pressure of 180 lbs. per square inch, showing that with a much less pressure of air than was used an ample supply

of steam at that pressure could be relied on. As a crucial test of its effect on the construction and the fitting of the tubes of the boiler, the fire (which was in a glowing state at the time), was at 3·20 P. M. as quickly as possible withdrawn, and every access for the surrounding air to reach the interior of the furnace allowed; but on examination not the least sign of a weep, or anything approaching it, from any of the tubes was perceptible—a fair proof of excellent workmanship and the soundness of the principle upon which the boiler is designed.

The boiler is in form and construction so exceedingly simple, yet, at the same time, so novel, that we may fitly conclude our notice of its trial with such a description of it as should be understood by all our readers. In form, looking at it from the front, it is like the Roman capital letter A, surmounted by a circle at the point where the two sides of the letter meet. The circle is a cylindrical shaped vessel or chamber, some 7 ft. 6 in. long, into which the two sides of the letter, which are a series of small copper tubes 1 in. in diameter, penetrate, the lower ends of these being fitted into the serifs or feet of the letter, which in the boiler are semicircular bottomed chambers. The cross bar of the letter—but lower down than in it—would represent the fire-grate bars. Here we have the whole boiler. Water is pumped into the upper cylindrical chamber, flowing down and filling the side legs or tubes, and is continued until the upper chamber is nearly half full. The fire is made on the cross bars between the side legs, and the flame and radiant heat, passing in among the tubes, boil the water in them and convert it into steam, which rises in them to the surface of the water in the upper chamber, and is there collected and confined until required for use. The circulation of the water is here absolutely perfect, the rows of tubes nearest the fire acquire the greatest heat, and the water in them is, in consequence, made sensibly lighter and ascends, while that in the outside rows, being cooler, and therefore heavier, follows the natural law and descends, and takes the place of the previously heated water, thus keeping up a continuous movement and circulation of it.

In confirmation of this efficient circulation of the water in the

boiler under description, the evaporation in it on the trial was calculated to have reached 12,500 lbs. of water per hour, or 100,000 lbs. for the eight boilers, to be fitted in the *Hornet*. A comparison of this with the two locomotive boilers of the *Havock*, whose evaporation was 54,880 lbs. per hour, her engines indicating 3,400 horse power, would give the boilers of the *Hornet* a power equal to 6,250 indicated horse, an amount largely in excess of what would ever be required from them.

Comparing the weights of the two sets of boilers, those of the *Havock*, when full, weighed 54 tons, while the *Hornet's*, complete, with all fittings, will not exceed 43, or a saving of 11 tons, which, in vessels of the class, is considered by the naval authorities an item of first importance.

ALUMINUM YACHT *VENDENESSE*.

This small yacht, launched at St. Denis during the first week in December, is the first vessel ever built of aluminum. She belongs to the Count de Chabannes, and "Le Yacht," from which this information is taken, says that she was originally intended to be of wood, and that she has been built solely for racing purposes. When the change from wood to aluminum was decided upon, the water line was lengthened and the lines fined somewhat. The working of this metal naturally presented many difficulties at first, and many trials were made before the best way could be determined, especially in riveting the plates to the steel frames and beams. After completion she was thoroughly tested for water-tightness of hull, and, after launching, for strength and stability; the tests were highly satisfactory. Her particulars are:

Length on water line, feet and inches	39–4
Length on deck, feet	57
Breadth, extreme, feet and inches	9–4
Draught, extreme, feet and inches	8–4
Displacement, tons	15
Weight of ballast, tons	11
Sail area, square feet	6,360
Thickness of aluminum deck (3 mm.), inch	.118
Number of water-tight compartments	2

About one ton of aluminum and one and a half tons of steel were used in her construction, and her hull is said to be 40 per cent. lighter than it would have been if made of wood. It has been coated with a special paint, put on similarly to anti fouling paint, in order to preserve it from the action of the sea water.

The aluminum plates used in the construction of this craft are said to be the first ever made of such dimensions, and were rolled by M. Charpantier-Page, at Valdois, France.

BOILER EXPLOSION ON THE FRENCH TORPEDO-BOAT *SARRASIN*.

On the 13th of January, while this boat was making her speed trials, a boiler exploded, fatally injuring an engineer officer, and a machinist and two firemen of the French navy, and an engineer of the Cail Works, the builders of the machinery. "Le Yacht" states that she had made three runs over the base, and was just about to begin the fourth one when the steam gauge in the conning tower showed that the pressure had suddenly dropped from 155 to 115 pounds. The engineer officer and the engineer representing the contractors immediately repaired to the fire room to ascertain the cause, but had scarcely got there when an explosion occurred, and almost immediately all the people in the fire room, terribly burned and scalded, scrambled up the hatch.

The boiler which exploded is of the Babillot type, designed so as to obtain a large amount of heating surface in proportion to its dimensions. The elements are each composed of a 6-inch pipe, within which there is another, the space between the two being filled with water, the heated gases passing around the outside of the large tube, and through the inside one, the envelope of water, according to "Le Yacht," being only one-tenth of an inch thick ($2\frac{1}{2}$ mm.).

An experimental boiler of this type was tried in a small boat, and after a number of modifications were made the test was so far successful that its use was permitted in the *Sarrasin;* the special boilers for this boat were tested on the dock before being put on board. She went through the preliminary trials without

difficulty, and then steamed unaided from Bordeaux to Rochefort, where the full speed trials were made.

Numerous causes have been assigned for the explosion, the most generally accepted one being faulty feed, the circulation apparently being a forced one. As a result of it, orders have been given to take these boilers out of the *Sarrasin* and out of the *Tourbillon*, a sister boat.

These boats are 144.3 feet long, 13.12 feet beam, and of 104 tons displacement. They have twin-screw engines of 1,000 I.H.P., and were designed for 20.5 knots. They have two tubes and three 47-mm. rapid-fire guns.

MERCURY FOR TEST PURPOSES.

At a recent meeting of the American Society of Mechanical Engineers, Professor Carpenter, of Cornell University, read a paper on "Constants for correcting indicator springs that have been calibrated cold." The "American Machinist" says that in answering questions on it Professor Carpenter stated that during some tests made at Cornell, in which a mercury column was used to indicate pressure, the results obtained were so far outside the range of probability as to cause an investigation, and at length it was found that the mercury, which had been purchased at a drug store and came in a bottle marked "pure," had a specific gravity of about 11, or 15 to 20 per cent. too low. Afterwards, wanting a metal which would fuse at a low temperature, they prepared an amalgam of 50 per cent. mercury, the rest being tin and lead, expecting this to fuse at 106 degrees. It was found, however, that this mixture, which was only one-half mercury, looked and acted in all respects like mercury and would readily have been taken for pure mercury unless particular investigation of it were made, the conclusion being readily drawn that some precautions must be taken to obtain pure mercury for use in determining pressures.

QUESTIONS IN PARLIAMENT.

The "Marine Engineer" says that some very interesting statistics have been elicited from the Naval officials in the House of

Commons recently by members of an inquiring turn of mind. Why the questions are put it is not always easy to discern, but here are some of the replies: The annual cost of the powder used by the Navy for saluting is £1,585. The annual cost of the effective list of accountant officers is £130,060; of the chaplains, including allowances to ministers of religion, £33,253, and of the domestics, £94,164. The average age of the Indian troop ships is 26 years and 6 months, and their average rate of speed 10.9 knots an hour. There is accommodation in the existing training ships for 5,706 boys, while the boys under training are 3,700 in number, and there are 4,594 boys available for sea service. There are 5,791 boys borne on the books of the training ships, but 220 are in hospital, and there is usually a proportion amounting to about 3 per cent. in hospital during the winter months. The annual cost of a battleship during commission, including repairs, maintenance, sea stores, coal, pay and victualing, is estimated to amount to £501,000. Out of 77 armor-clad vessels owned by Great Britain, 40 are armed with muzzle-loading ordnance of obsolete type. Most of these vessels, however, are supplied with modern quick-firing guns on the B.L. principle for their auxiliary batteries. There are 19 naval and 17 military officers in the Naval Ordnance Department; that the latter should be so employed is in accordance with an arrangement made by the Admiralty with the Treasury when the stores were transferred from the War Office charge. As vacancies occur in certain of these appointments they will be filled by the promotion of warrant officers in the Navy.

BRITISH ORDNANCE TRIALS.

The tests of the 10 inch guns and mounts of the *Centurion* and of the 12-inch ones of the *Revenge* are thus reported in "Engineering":

The new battleship *Centurion* has finished her ordnance trials, which were of special interest, owing to the mounting and loading gear being by Sir Joseph Whitworth & Co. The armament consists of four 10-in. 29-ton guns mounted in redoubts; ten 4.7-in. quick-firing guns, of which four are carried in armored case-

mates; eight 6 pounder and twelve 3-pounder Hotchkiss quick-firing guns; a complement of field and machine guns, and seven torpedo tubes, two being submerged. The chief features in the ship are the disposal and mounting of the main armament, which is arranged to fire through an angle of training of 240 degrees in pairs or independently, and notwithstanding the weight, which amounts to about 200 tons, including shields, guns, mountings and turntables, can be worked by either hand or steam appliances, or by both in combination. The mountings have been specially constructed to secure high-angle fire.

The heavy guns and their mountings are contained in a couple of redoubts, which are, in fact, a blending of the two methods in vogue (turrets and barbettes); that is to say, while the 10-in. walls of the redoubts are circular and vertical like a turret, they are fixed like a barbette. They differ from the barbettes in the fact that they are built up in segments and not in flat slabs. The redoubts are topped with nickel-steel hoods or shields for the protection of the gun crews, these shields being carried on the turntables and rotating therewith. The shields, which are pear shaped in plan, slope upwards and backwards, after the manner of a barbette, an arrangement which gives an effective resistance to horizontal fire of 11 in., although possessing an actual thickness of only 6 in. The obliquity of the armor has also the additional advantage of causing the shot to glance off before penetration. Briefly, the arrangement may be described as a turret revolving within a fixed barbette.

The supply of ammunition is arranged in such a way that the guns can be loaded at any angle of training, without coming to a fixed loading station after each discharge. So far as elevation and loading are concerned, they can be manipulated by hand, and the training is effected from the sighting stations by a couple of steam engines, fitted on the machinery deck, which drive vertical shafts provided with pinions, gearing into a rack on the turntable. Hand gear is also supplied as an auxiliary. It is also intended to fit electro motors to the elevating apparatus, designed for a large angle of fire, viz: minus 7 degrees, plus 35 degrees elevation. The loading station being almost horizontal, the elec-

tro motors will be valuable adjuncts to the hand-elevating appliances when the guns have to be moved through the angle from loading position to maximum elevation or thereabouts. The motors, however, are merely auxiliaries, as the elevation can be accomplished by the manual gear, though less expeditiously. The front of the shield is sloped at an angle which allows of the guns being moved through an exceptional range of 42 degrees without requiring unduly large ports. The guns are mounted upon two gravity-return slides, which are provided with hydraulic brakes for checking recoils. Powerful springs insure the return of the guns, even when the ship is considerably heeled. The guns are secured to the turntable, which is carried on a live-roller ring. The lower path is supported on a structure entirely independent of the redoubt, which is built above the upper deck to the base of the shield and extends downwards to the armored deck, and consequently completely incloses the turntables, roller paths, ammunition hoists and the training mechanism.

In the center of the redoubt is a tube extending from the magazine deck to almost the underside of the turntable. It is divided vertically into two compartments, each of which is fitted with guides and cages, one of them worked by hand being for emergency use, the other having steam hoisting gear. The ammunition is lifted into the cages from the magazines and conducted to the top of the central tube, which terminates in a chamber secured below the turntable, and revolves with it around the tube. This chamber is fitted with two hoists, one behind each gun, and each capable of carrying a projectile and a couple of half-charges, and delivering in rear of the breech in readiness for loading. The hoists are worked by windlasses by men inside the chamber. The "ready supply" of projectiles are stowed around the sides of the chamber, about sixty rounds being thus disposed of. An electro motor is being fitted to the upper hoist for rapid transport of the charges to the guns. The sighting arrangements are similar to those in many other of Her Majesty's ships, except that, owing to the large angle through which the guns move, special arrangements have had to be adopted to insure the angular movement of the sight bars through the ex-

treme range. Each shield has two sighting hoods, from which either of the guns in the redoubt is trained and elevated, the latter operation being effected by means of an electric switch or by a handwheel. The guns fire the usual 500-lb. projectiles with 252 lb. of B. cocoa powder. The normal length of recoil is 30 inches, and the control is effected by a central tapered bar.

As carried out, the order of firing, according to the "Times," was as follows:

	Gun.	Rounds.	Charge.	Elevation.	Bearing.	Recoils.
						In.
After barbette.	Left gun	1	Reduced...	2 degrees...	16 deg. abaft starboard beam...	*
		2	Full.....	6 " ...	10 deg. before port beam.....	30
		3	"	15 " ...	10 deg. abaft starboard beam...	30
		4	Half.....	34½ " ...	Port beam	17¾
		5	"	34½ " ...	Starboard beam	21
	Right gun	1	Reduced...	2 " ...	16 deg. abaft starboard beam...	30
		2	Full.....	6 " ...	10 deg. before port beam.....	30
		3	"	15 " ...	10 deg. abaft starboard beam...	30
		4	Half.....	35 " ...	Port beam.....	13
		5	"	34½ " ...	Starboard beam.....	21½
Fore barbette.	Left gun	1	Reduced...	Horizontal...	Port beam.....	30
		2	Full.....	10 degrees...	" "	30
		3	"	10 " ...	" "	30½
		4	Half.....	35 " ...	Starboard beam.....	16
		5	"	35 " ...	" "	22
	Right gun	1	Reduced...	Horizontal...	Port beam.....	30
		2	Full.....	10 degrees...	" "	30½
		3	"	10 " ...	" "	30½
		4	Half.....	35 " ...	Starboard beam.....	16
		5*	"	35 " ...	" "	17

* Not recorded.

It will be observed that there was great regularity of recoil. The rounds discharged from each of the four guns were in excess of the usual number, extra tests being deemed indispensable in a case of a system not hitherto put to the test. The third and fifth from the guns in each barbette were discharged simultaneously. Half-charges were used at 35 deg. elevation, because the mountings are only designed for reduced charges at high elevations. After each salvo careful observations were carried out for the purpose of ascertaining whether any deflection in the turntables had taken place during the double strain. Not the slight-

est deviation from the horizontal was noticed in any direction. The trials throughout were in every respect successful. There were no hitches, the only defects recorded being confined to a few minor fittings which were of a temporary character, owing to the trials having been hurried on to enable completion of ship in matters dependent on trials. When completed for sea, the *Centurion* will relieve the *Impérieuse* on the China station.

The *Revenge* completed her gunnery trials at Portsmouth on the 18th of January. As her smaller gun-fittings had been satisfactorily tested on the previous day, the day was devoted to firing from her 6-in. quick firing guns and her barbette armament of four 67-tonners. The principal interest was centered on the after barbette, the right gun of which was experimentally mounted upon an improved slide. The original Elswick arrangement, as fitted to the other heavy guns, consists of a single recoil cylinder, having a large number of spring-loaded valves attached at the rear of the recoil press. This system was considered objectionable, on account of the liability of the valves to get out of order and to permit the gun and carriage to recoil without control, and it was deemed advisable to substitute a simpler and more trustworthy arrangement, with as few loaded valves as possible. It was decided to apply what is known as "the pull-and-push" method, requiring two cylinders, but a single loaded valve, which can readily be examined and adjusted as circumstances demand. The system, however, is only new in its application, as it is merely a development of the original Vavasseur mountings as first adopted in the service. In the ships about to be built the "pull-and-push" system is to be still further simplified; instead of two there will be only one recoil cylinder per gun, and the presses will not be interfered with, the running in being performed by the force of the recoil, and the running out by means of springs. In the *Revenge* the running in of the gun on the slides is accomplished by the admission of water to one cylinder, and the running out by admitting it to the other. It may be mentioned that the principle of recoil presses fitted with valve keys is already extensively applied to small mountings.

Three rounds were fired on the 18th instant from each gun in the after barbette, with reduced and full charges (that is to say, with 472½ lb. and 630 lb. of S.B.C. powder, carrying a projectile weighing 1250 lb.), and an extra round from the right gun with an extreme elevation of 13¼ degrees, for the purpose of securing a diagram of pressures. The new mounting was perfectly successful, the only noticeable feature being the fact that the length of the recoil was practically the same under the reduced as with full charges. With three-quarter charges the recoil of the right gun was 4 ft. 7¼ in., and that of the left gun 4 ft. 7 in. With full charges the recoils of the twin guns were substantially identical, that of the right gun being 4 ft. 8¼ in., and of the left 4 ft. 7 in., when fired simultaneously with 10 degrees of elevation. The difference is due to the application of different principles. In the hydraulic system the resistance behind the gun is already formed, and the length of the recoil varies with the charge, while under the bar system the resistance is generated by the recoil itself, and may be regarded as practically constant except as regards velocity. There were no misfires during the firing.

AN EVAPORATOR EXPLOSION.

A singular explosion occurred recently on board the English battleship *Resolution*, resulting in seriously burning an artificer, who was examining one of her evaporators. It appears that she has two of Weir's evaporators, one fitted on the starboard side and the other on the port side of the engine room. Since the vessel has been in commission the water which has been distilled has proved brackish, and although this might be due to working the evaporators at a low pressure (which would cause priming), it was decided to make an internal examination to see if there was an alternative reason for the unsatisfactory results obtained.

One of the evaporators had been examined and the manhole plate on the other removed preparatory to examining it. In order to make a proper examination it was necessary for the artificer to get inside, but just as he put his light to the opening

an explosion occurred, his clothing caught fire, and he was badly burned about the arms, face and neck.

An official inquiry was made to ascertain the cause of the explosion, but no definite cause was assigned. The general belief seems to be that the gas was hydrogen, and that its presence was due to the fact that zinc plates had been suspended in the evaporator to prevent corrosion of the heads and shell, the tubes being of copper.

SHIPS.

UNITED STATES.

Olympia.—The official trial of this vessel was made in Santa Barbara Channel on the 15th of December, over a course 42.98 knots long, one run being made in each direction, and was remarkably successful. The following are the mean results:

Speed in knots	21.686
Revolutions per minute	139 22
Steam pressure in boilers, pounds	166.5
Vacuum	25.2
Air pressure in inches of water	2.04
I.H.P. main engines, air and circulating pumps	17,035
Mean draught, feet and inches	20–8¼
Displacement, tons	5,570

An extended account of the trial, with description of the hull and machinery, will appear in the next number of the JOURNAL.

Montgomery.—The official trial was made in Long Island Sound on the 19th of January, with most satisfactory results, the speed exceeding that of the sister ships, *Detroit* and *Marblehead*. As the *Detroit* and *Montgomery* differ somewhat in details from the *Marblehead*, a full description of the *Montgomery*, with the trial data of her and the *Detroit*, will probably be given in the next number of the JOURNAL.

The following are the principal data of the trial:

Speed in knots	19.056
Revolutions per minute	180.27
Steam pressure in boilers, pounds	165
Vacuum	26
Air pressure in ash pits in inches of water	1.4
I.H.P. main engines, air and circulating pumps	5,527
Mean draught, feet and inches	14–6¼
Displacement, tons	2,091

Machias and Castine.—The recommendations of the Board appointed by the Secretary of the Navy to determine the most effective means of increasing the metacentric height of these vessels has been approved, and will be carried out at the New York Navy Yard. The recommendations were to cut the ships in two about six feet abaft the midship section, and put in a section 14 feet long; to reduce the height of the smoke-pipe 10 feet; to replace the 28 foot steam cutter by a 26-foot one; to remove the center bridge and the fore-and-aft one; to omit the wire hawsers, reels and nippers; to reduce the size of the masts, and to remove the armored sponsons. The section thus put in will come just abaft the boilers and will form a large coal bunker, which will increase the bunker capacity about 83 tons; the bottom of it will be fitted as a fresh-water tank, holding about 16 tons, into which will also be put about 5 tons of ballast. As thus altered, the displacement of these vessels will be 1,281 tons, the draught of water being 12 feet 3 inches.

Gunboat No. 7.—The contract for her construction has been awarded the Newport News Shipbuilding and Dry Dock Company. Since the opening of bids, the Department has decided to increase her beam 2 feet, so that she will now be 220 feet on the water line, 38 feet beam, 11 feet draught, and will displace 1,371 tons.

Gunboats 8 and 9.—The Newport News Company was also awarded the contracts for these vessels, whose displacement will be 1,313 tons on a mean draught of 8 feet 7½ inches.

ARGENTINE REPUBLIC.

Patria.—Twin-screw torpedo cruiser building by Laird Bros., Birkenhead, was launched December 28. She differs from the general type of torpedo cruiser hitherto built by this firm in that she has a flush spar deck instead of a poop and forecastle. She is 250 feet long, 30 feet beam, and 16 feet deep, and displaces about 1,180 tons; the speed contracted for is 18 knots.

The machinery, which is complete in Messrs. Laird's shops ready for putting on board, consists of two sets of triple-expansion engines of 4,250 horse power, each driving a three-bladed

propeller with steel boss and manganese bronze blades; distillers and evaporators of large capacity, and complete electric installations in duplicate are provided. The boilers are of steel, four in number, of the wet-bottom locomotive type, working at a pressure of 155 lbs. per square inch, to be worked under the closed-stokehole system. The armament will comprise quick firing guns, machine guns, and five torpedo tubes.

BRAZIL.

Aurora.—This small twin-screw torpedo gunboat, built by Armstrong, Mitchell & Co., was purchased by the Brazilian Government about the same time that the *El Cid* (*Nictheroy*) and *Britannia* (*America*) were purchased in this country. She is 197 feet long on the water line, 20 feet 2 inches beam, 12 feet 4 inches deep, 8 feet draught, and of 450 tons displacement. She has twin screw triple-expansion engines, built by Scott & Mountain, Newcastle, with cylinders 18, 26½ and 38¼ inches diameter by 17 inches stroke, designed for 2,300 I.H.P., with which she was expected to make 18¼ knots. Her armament consists of two 30-pounders and four 3-pounders, rapid fire, and three torpedo tubes.

Five 120-ton torpedo boats, purchased about the same time in Germany, recently reached Pernambuco, having made the entire voyage from Elbing, where they were built by Schichau, under their own steam and without a convoy. Their average speed from St. Vincent to Pernambuco was 12 knots. The crew (German) of each consisted of one officer and fifteen men. The boats are rated at 26 knots.

ENGLAND.

Battleship Steam Trials.—"Engineering" has the following excellent editorial on the trials of these ships: The ten battle ships constructed under the Naval Defence Act have now completed their steam trials. They were ordered towards the latter end of 1889—six from the dockyards and four from private establishments.

Our purpose is to analyze the results obtained on the steam trials of the several vessels with a view to accentuating some of

the irreconcilable points in the comparison, as indicating some necessity for either greater care in acquiring data or a change in the method of establishing the steam power or speed of our ships of war. In the first place, it may be interesting to indicate the main features of the design of these vessels and their machinery. Eight of the vessels are alike, and belong to what is known variously as the *Royal Sovereign* or *Ramillies* class. The only essential difference is that one of them, the *Hood*, is fitted with turrets, whereas the others have their large guns fitted *en barbette*. This has been done as a concession to the view still held by a few in favor of the extra protection afforded by the turret, although in official circles the barbette is more favored. Practical experience in war can alone determine this as well as many other questions. The dimensions of these vessels are: Length, 380 ft.; breadth, 75 ft.; and at their loaded draught of 27 ft. 6 in., their displacement is 14,150 tons.

In addition to the compound armor of 18 ins., extending for about 250 ft. of the length of the vessel, with thwartship armored bulkheads forward and aft, there is an auxiliary armor plating 4 in. thick from this belt right up to the top of the hull, affording protection to the deck from which the large installation of 6-in. quick-firing guns are fired. The vessels have a freeboard which is exceptionally high for a modern battleship. In the matter of big guns, too, the idea of concentration in a few weapons has not been followed, and there are two 67-ton guns forward and two aft; while in the matter of auxiliary armament the vessels are much more effectively armed than any previously constructed British battleship, more particularly in view of the part to be played in future warfare by the torpedo-boat, for there are on board ten 6-in. quick-firers, sixteen 6-pounders, and twenty-two machine guns, beside means for launching seven torpedoes simultaneously.

But it is with the machinery that we have for the moment most concern, and it would be idle to pretend that thoroughly satisfactory results have in all cases been attained. The success is a relative quantity. The ships and engines were designed so that the power developed would be 13,000 indicated horse power,

and the speed 17½ knots. Now, in no case has this power been attained for even the short stipulated period of four hours, and although the speed in most cases was 17½ knots or over, with less power developed, the displacement in such cases was considerably less than it would be when the vessels are fully equipped. The story is the familiar one of leaky tubes, the evils and remedy for which have been so exhaustively discussed. After it was found that the boilers of the first vessel tried, the *Royal Sovereign*, could not withstand the air pressure necessary to develop the contract power, the Admiralty determined that none of the other vessels should be subjected to the 13,000 indicated horse-power test, but that 11,000 indicated horse power would be regarded as sufficient. The engines for the eight battle ships of the *Royal Sovereign* class are alike in general dimensions. In no case has any great variation been made in the design. Some slight alterations in detail have been introduced by the respective firms constructing the machinery, but these are not material. Moreover, there were only four contracting firms. Messrs. Humphrys, Tennant & Co., London, fitted the engines to all the four dockyard-built ships—*Royal Sovereign*, *Empress of India*, *Hood* and *Repulse;* Messrs. Palmer, Jarrow-on-Tyne, to the *Revenge* and *Resolution;* Messrs. Thomson, Clydebank, to the *Ramillies*, and Messrs. Laird Brothers, to the *Royal Oak*. The cylinders are 40 ins., 59 ins. and 88 ins. in diameter respectively, the stroke being 4 ft. 3 ins. As a rule, the cylinders are separate castings, and are braced together by steel rods. The framework differs from that ordinarily adopted, the cylinders being carried on turned pillars, with the usual A-frame at the back, the crosshead slipper guides being formed in the latter. The condensers, with 14,000 square feet of cooling surface, are entirely separated from the engine frames. There are eight single-ended boilers, with a total surface in tubes of 17,016 square feet, and in furnaces of 3,018 square feet, giving a total of 20,034 square feet, while the grate area is 718.6 square feet. The area through tubes is 97.6 square feet, and the diameter of tubes 2½ ins. The furnaces are divided into pairs, with a combustion chamber for each pair. In the forced-draft trial of the *Royal Sovereign* it was found that during the fourth hour

of the run the tube ends commenced to leak; the air pressure throughout the three hours had been 1.6 ins., and the mean power worked out at 13,312 indicated horse power. Thus it was that the vessels subsequently tried were only subjected to an 11,000 indicated horse power test.

The natural-draft trials are all on the same basis; perhaps in some cases the fans were worked at a higher speed, affording a greater air pressure, which may account for the differences in power; but on comparison a great variation in the relation between power and speed is noticeable. We have, in tabulating the results, given the exact displacement on trial, without which no comparison could be accurate. The *Royal Sovereign*, for instance, was loaded to her full designed draught, and displaced 14,262 tons, and with 9,661 indicated horse power, had a speed of 16.375 knots. The *Empress of India*, on the other hand, had 1,000 tons less displacement, with only a slight reduction in power, and yet her speed was only 15.25 knots, more than a knot less. The *Repulse*, on the other hand, had 2,000 tons less displacement, with practically the same power, and her speed was 17.78 knots. It is pretty evident, therefore, that all three cannot be correct, especially as none of the vessels experienced abnormal weather. The *Hood*, too, shows a variation, but seems to bear out the results of the *Royal Sovereign*. The *Ramillies*, *Resolution*, and *Royal Oak* seem to agree fairly well, but the *Revenge*, with a similar displacement, but slightly less power, seems to have got more than half a knot more speed.

The forced-draft results show still more remarkable results. We have not thought it desirable to give the air pressure of the forced draft, as in no instance was any effort made at uniformity. In some cases, indeed, the variation was from considerably over 1 inch to ¼ inch. There is, of course, great variation in the mean air pressure and the power, but we do not think that this need at the present enter into the comparison. Careful stoking and supervision certainly insure a high evaporative efficiency, and consequently a satisfactory power for the air pressure recorded. Moreover, careful workmanship always affects the result more or less. The *Ramillies* only required a mean air

pressure of ⅛ inch to get her power, and in a subsequent run, when on her way to the Mediterranean, where she is now flagship, a steam trial was undertaken with results which corroborate this record. The *Revenge* worked with a mean pressure of .46 inch, while the *Resolution*, by the same firm, required nearly double that pressure, and did not materially add to the power. The *Empress of India* and *Royal Oak* required about 1 inch, but it is said in the case of the latter that the stoking was bad. The mean air pressure in the case of the *Repulse* was .91 inch. The *Royal Sovereign* took 1.6 inches air pressure to develop her 13,363 indicated horse power, and at her load draught made 18 knots, which seems to demonstrate that so far as the model of the ship was concerned the deductions of the designer were accurate, and allowed a margin for emergency. The same speed was got by the *Empress of India*, but the displacement was 1,000 tons less, and the power 1,700 less. It would, therefore, appear as if the power for a given speed increased at 1¾ times the displacement. But again this hypothesis is upset, for if comparison is made with the *Repulse*, which also got the same speed—indeed, a trifle more—the power only increased *pari passu* with the displacement. In the case of the *Hood*, however, we find that, although the displacement is but 650 tons short of that of the *Royal Sovereign*, the power, being 2,000 less, only gave 16.9 instead of 18 knots. The *Ramillies*, *Resolution*, *Revenge* and *Royal Oak* again agree closely in all except the speed. The *Revenge*, too, it should be recalled, experienced very bad weather, which doubtless explains the small difference in speed on the natural and forced-draft conditions.

The *Barfleur* and *Centurion*, included in the table, are not of the same class. Their length is 20 ft. shorter, they have 5 ft. less beam, and 2 ft. less draught of water, so that the displacement is 3,600 tons less. This was determined upon to enable the vessels to pass through the Suez Canal, which of itself is a great advantage. The armor, as well as armament, is lighter, the main belt being 12 ins. instead of 18 ins. thick, but they have the same auxiliary 4-in. armor on the upper part of the hull, above the main armor, exposed to the attack of an enemy's quick-firing

DETAILS OF RESULTS OF STEAM TRIALS OF NAVAL DEFENCE ACT BATTLESHIPS.

Ships.	Draught of Water. Forward. Ft.	In.	Aft. Ft.	In.	Displacement.	Indicated Horse Power. Starboard.	Port.	Total.	Speed by Log.
									Knots.
Royal Sovereign N.D.	27	0	28	0	14,260	4,928	4,733	9,661	16.375
Royal Sovereign F.D.	26	8	28	0	14,150	6,653	7,710	13,363	18.
Royal Sovereign 4 runs M.M.	27	0	28	0	14,260	4,879	4,597	9,476	16.32
Royal Sovereign 4 runs M.M	27	0	28	0	14,260	4,935	4,844	9,779	16 77
Empress of India N.D.	25	4	26	4	13.210	4,762	4,746	9,508	15.25
Empress of India F.D.	24	11	25	9	13,070	5,978	5,647	11,625	18.
Repulse N.D.	22	5	25	9	12,100	5,000	4,588	9,588	17.78
Repulse F.D.	22	5	25	9	12,100	5,997	5.518	11,315	18.2
Hood N.D.	25	6	27	4	13,580	4,636	4,903	9.539	15 75
Hood F.D.	25	3	27	4	13 500	5,694	5.752	11.446	16.9
Ramillies N.D.	24	3	26	1	12,800	4,718	4,725	9,443	16 75
Ramillies F.D.	24	3	26	1	12,800	5,847	5,724	11,571	17.25
Resolution N.D.	24	4	25	9	12,730	4,592	4,656	9,248	16.73
Resolution F D.	23	10	25	8	12,530	5,683	5,718	11,401	17 92
Revenge N.D.	24	2	25	9	12,680	4,614	4,563	9,177	17.375
Revenge F.D.	24	1	25	8	12,610	5,694	5,830	11,524	17.5
Royal Oak N.D.	24	6	25	6	12,690	4.477	4.744	9,221	16 5
Royal Oak F.D.	24	4	25	5	12,610	5.689	5.882	11,571	18.27
*Centurion** N.D.	25	0	26	0	10,590	4.785	4.918	9.703	17.5
*Centurion** F.D.	25	0	26	0	10,590	6,401	6,773	13,174	18.51
Barfleur N.D.	21	6	25	6	9,500	5,003	4.931	9,934	17.165
Barfleur F.D.	22	0	25	6	9,650	6,580	6,583	13,163	17 537

*The *Centurion* and *Barfleur* are of a different type to the others, as indicated in the article.
N. D. means natural draft, and F. D. forced draft, the duration of the trial under the former condition being eight hours, and under the latter four hours.

guns. They have also four guns mounted in pairs *en barbette* forward and aft, but these are 29-ton guns instead of being 67-ton, while they have ten 4.7-in. quick-firing guns instead of ten 6 in. guns, and eight 6-pounder guns instead of sixteen in the *Royal Sovereign* class. The machine guns, however, are about the same in number, and they have the same amount of torpedo armament. The engines were constructed by the Greenock Foundry Company (Messrs. Scott), and in general design are similar to those of the *Royal Sovereign* class; but here the engines were driven under forced draft, the boilers withstanding an air pressure of 1½ ins. without discovering any weakness. The *Barfleur* on natural-draft run experienced rather worse weather than her consort, which explains the discrepancy; but it is difficult to explain the remarkable difference between the forced-draft speeds of the two, particularly as the power was the same. The speed of the *Barfleur* is a knot less, notwithstanding, too, that the displacement was nearly 1,000 tons less.

It seems difficult, under the circumstances, to arrive at any conclusion, especially in respect of the *Royal Sovereign* class. The discrepancies seem irreconcilable. Either the power developed does not represent a fair mean on the eight and four hours' run, or the speed is inaccurate. It has been said that the horse power can only be assumed as within 5 per cent. of accuracy, and if that be so it were well that a change were made in the conditions of trial. Diagrams are taken every half hour, and the mean of the lot taken as a fair indication of the result. This may seem satisfactory, but we fancy it will be admitted that it is quite possible to work the engines to get an abnormal result at the moment the diagrams are taken, especially when there is half an hour in which to work. The taking of diagrams more frequently, and the careful noting of all circumstances, would give results of much more value to the contractors as well as the Admiralty. We do not know that there would be much gain to the country except in valuable data being got, but clearly greater confidence could be placed in the results. The speeds recorded by logs are certainly not thoroughly accurate. That is universally admitted; so that there is no public record of the performances so far as speed is concerned. No doubt the Admiralty authorities have

the exact data of the performances on the measured mile of the *Royal Sovereign*, but the question may come in as to whether or not this was affected by drag consequent on a limited depth of water—a possibility which has been clearly established in the case of other high-speed steamers. Certainly, if this were eliminated and the exact revolutions necessary for the measured mile ascertained, it would be easy, and probably much more accurate, to determine the speed of a vessel by using her own screws as the log.

Royal Oak.—This battleship, referred to in the preceding list, was built by Laird Brothers, and the following details of her construction and armament will answer for the other vessels of the same class:

Length, feet	380.
Breadth, feet	75.
Mean draught, feet	27.5
Displacement, tons	14,150
Water-tight compartments	220
Freeboard, forward, feet	19.5
Freeboard, aft, feet	18.
I.H.P., natural draft	9,000
I.H.P., forced draft	13,000
Speed, natural draft	16.
Speed, forced draft	17.5
Armor, length of belt, feet	250
Armor thickness, maximum, inches	18
Armor thickness, minimum, inches	14
Armor, lower edge below L.W.L., feet	5.5
Armor, upper edge above L.W.L., feet	3.0
Protective deck, length forward, feet	76
Protective deck, length aft, feet	72
Protective deck, thickness, inches	2½
Barbettes (2), thickness, inches	17
Barbettes (2), length, feet	48
Conning tower, forward, thickness, inches	14
Conning tower, aft, thickness, inches	3
Weights:	
Total armor and backing, including protective deck, tons	4,550
Machinery, spare gear, etc., tons	1,100
Armament, tons	1,910
Coal, tons	900
Anchors and chains, tons	130
Hull with armor, etc	9,500

The protective deck is entirely below water, and extends only from the stem and stern posts to the armor belt. The ends of the belt at each side are joined by transverse armored bulkheads, and above the belt there is a 3-inch deck running the full length of the armor. Above this there is another belt four inches thick on the sides, and three inches athwartships, behind which there are side coal bunkers.

The upper deck extends from stem to stern without a break, and above it is a continuous bridge deck extending the whole length between the barbettes, and on this deck are the conning towers surmounted by the navigating bridge and chart house. The boats, of which there are 21, include two 56-foot torpedo boats. Derricks for lifting the boats in and out are fitted to each mast.

There are two military masts with armored tops, and two smoke pipes with their axes in the same athwartships plane.

The armament consists of four 13.5 inch 67-ton guns, 23 feet above the water line, mounted in pairs in barbettes forward and aft, firing a 1,250-pound projectile, with a powder charge of 630 pounds; ten 6-inch rapid-fire guns, four of which are on the main deck and six on the upper deck, all protected by 6-inch shields; sixteen 6-pounders, nine 3-pounders, eight machine guns and two 9-pounder field pieces. The 13.5-inch guns are worked by hydraulic machinery and the 6 inch by hand. The torpedo armament consists of seven tubes, five above water and two submerged. The number of torpedoes carried is eighteen.

The machinery differs little in the several ships, so that the following description of the *Royal Oak*, principally from "The Engineer," London, will give a fair idea of that of all the class except in the matter of engine framing:

The propelling machinery consists of two sets of triple-expansion engines, each in a separate water-tight compartment, with the magazines between them. The cylinders are 40, 59 and 88 inches in diameter, with a stroke of 51 inches. They are entirely independent castings, and are bolted together by brackets. The receivers consist of copper pipes attached to gun-metal branches, and expansion-joint stuffing boxes. The whole of the cylinders

are steam jacketed, the working barrels of the high pressure being of forged steel, and those of the low and intermediate-pressure cylinders of cast iron; the slide valves for the high and intermediate pressure being of the piston type, whereas the low-pressure cylinders have flat double-ported valves. A special type of relief ring is fitted at the back of these flat valves. Balance cylinders are fitted to the high-pressure and intermediate valves, and assistant cylinders to the low, to reduce the strain on the valve gear as far as possible. The valve gear is of the double-eccentric link-motion type, and is moved by means of a double-cylinder starting engine. The columns are of wrought steel. The main condensers, which are of brass, have a collective cooling surface of 14,500 sq. ft. The water is supplied by four 18-inch Allen's centrifugal pumps, each driven by an independent engine. Suctions are also led to the bilges from these pumps, which give a total bilge-pump power of 4,400 per hour. The crank shaft for each set of engines is in three separate pieces, the cranks being set at 120° to one another. The crank, thrust and propeller shafts are all hollow, an 8-inch hole being bored through their entire length, and they are each forged from a solid steel ingot.

The thrust blocks and collars are of cast steel. The latter are lined with white metal, and are of the ordinary type. The screw propellers are four bladed, the blades and bosses being of gun metal. Steam is supplied by eight single-ended cylindrical return-tube boilers, working at 155 lbs. pressure per square inch, and being 15 ft. 4 ins. in diameter and 9 ft. 4 ins. long, each boiler having four corrugated furnaces 3 ft. 4 ins. in diameter. The total grate surface is 710 sq. ft. and the total heating surface 20,174 sq. ft. For the purpose of shutting off each combustion chamber from the others, and also for regulating the draft in same, separate dampers are fitted in the passage from each through the smoke boxes, and gear arranged to work the same conveniently from the stokehold floor. Following out the principle of subdivision, each pair of boilers is in a separate water-tight compartment, with independent coal supply, separate access to and from main deck, etc. The exhaust steam from the whole of the aux-

iliary machinery in the ship is led into an auxiliary exhaust pipe, which is connected both with the atmosphere by means of the auxiliary waste steam pipes carried up outside the funnels, and with the two auxiliary condensers, one in either engine room. Each of the latter condensers has its own air and circulating pump entirely independent of those for the main condensers, and worked by independent engines. The combined cooling surface of these two auxiliary condensers is 1,800 sq. ft.

In the main engine rooms there are also two double-cylinder turning engines, two evaporators with independent feed pumps, two distillers with circulating and distributing pumps, four No. 2 Admiralty-type main feed pumps, of ample size to supply the whole of the boilers in full power, and four double-cylinder double-acting bilge and fire pumps of No. 1 Admiralty type; a pump for pumping out the drain tank, and two ventilating fans 6 ft. in diameter, each driven by a separate steam engine. In the boiler compartment there are eight fans 5 ft. 6 ins. in diameter, each with its separate engine, for supplying the forced draft for the boilers, and also four double-cylinder double-acting auxiliary feed pumps of No. 2 Admiralty type.

On the platform, *débris*, and lower decks is placed the auxiliary machinery for the working of the ship, including steering engines, electric engines, and hydraulic pumping engines, as well as a fully equipped workshop and numerous store-rooms.

The natural-draft trial was made with .27-inch air pressure, the engines making 96.3 revolutions and developing 9,221 I.HP. The speed was 16.5 knots by patent log, but she was not down to her load draught.

The details of the forced-draft trial, the ship being 2 feet 7½ inches light, are:

Steam pressure	145.8	
Air pressure	.98	
	Starboard.	*Port.*
Revolutions	103.5	103.4
I.H.P.	5,689	5,882
I.H.P., collective	11,571	
Speed by patent log	18.27	

Revenge.—Built by the Palmer Ship Building Co. The engine framing is different from that of the *Royal Oak*. The front columns are forged steel, cylindrical, and the back ones cast steel, inverted frames, of box section. Each cylinder is supported at the front by two turned columns of forged steel, an additional column being placed under the low-pressure valve chest. A diagonal stay runs from the bottom of each front column up to the under side of the cylinders at the back, and the engines are further stiffened by an athwartship stay carried from each cylinder to the magazine bulkhead (between the engine rooms), at the level of the ammunition passage floor.

The following are the mean results of her trials under natural and forced draft:

	Natural Draft.	*Forced Draft.*
Steam pressure	149.8	147.
Air pressure	.19	.46
Revolutions	96.57	101.96
I. H. P.	9,177	11,524
Speed by patent log	17.375	17.5

The forced-draft trial was made in a rough sea, and on both the ship was drawing only 25 feet, corresponding to a displacement of 13,000 tons.

Resolution.—A sister ship to the *Revenge*, and built by the same firm, started from Plymouth, England, on the 18th of December, for Gibraltar, in company with the torpedo gunboat *Gleaner*. After getting into the Bay of Biscay, where she encountered a gale, she rolled so heavily and shipped so much water as to render it necessary to heave to. So much injury was done to the deck fittings and gear that her captain decided to run for Queenstown, where she arrived on the 23d. The account of her behavior was soon made public, and the following letter, written by one of her officers and published in the "Times" of the 28th, created the greatest alarm amongst those not familiar with the stability of these battleships:

Resolution, at Sea, December 22d, 1893.

My Dear —: In all my experience as a naval man I have never gone through such a terrifying time as I have during the last few days.

We left Plymouth last Monday for Gibraltar. In all this class of ship the stability question has, of course, played a great part. All the other vessels of this class were tested for stability before they left England, but in our case the stability is a matter of theory, based upon calculations made at the constructor's department, the result being that our maximum angle of stability is 38 deg., with a rapidly declining chance of righting until a vanishing point of 65 deg. is reached, when all is over.

Fancy the pleasant sensation of finding her rolling in moderate weather 42 deg. each way directly she got into the Bay. This did not occur only once. Our confidence in the ship having received such a rude shock, we on Wednesday last experienced a gale, the equal of which I have never seen. Between the squalls the sea rolled mountains high. Our fore bridge is 37 feet from the water and some distance from the bows. From that the approaching wall of water blocked out any view of the horizon. Forty feet is a low estimate of the height of these rollers. During the squalls the whole surface of the sea was torn up and simply driven along in a sheet of spray, mixed with hailstones. The sight and noise were horrifying.

All this time we steamed slowly, keeping her head to the sea, but knowing full well that any deviation of the helm, any breakdown of the engines or steam-steering gear, and we would broach to and capsize.

During the night of the gale the water came below in tons, and at one time the engine room had 5 feet of water in it. This ran a chance of putting the fires out. Everything was then closed up except one small hatchway amidships, well protected, and up and down this for 18 hours everyone of the 700 people in the ship had to go. The atmosphere below became filthy and poisonous. The next day, when the gale slightly moderated, and coal was running short, it became a question of what shall we do, but we dared not turn round for fear of her going over. At length, at 4 P. M. yesterday (Thursday), the sea had gone down sufficiently to allow of our altering course a couple of points and making for Queenstown, which we hope to reach this evening.

I have no fault to find with the gale or with the ship during the gale. She performed her part splendidly so far as it went. What is certainly a serious matter is this evident want of stability. There is not a man of mature age in the ship but feels he is in a thoroughly unsafe ship. . . . We ought not to leave England without being tested, and there ought most assuredly to be a redistribution of weights. . . .

Ever yours, ——.

Another officer in the "Naval and Military Record" said: Several attempts were made to put her off the wind and shape a course, but to no purpose, owing to the heavy sea; and although the course she was heading had to be altered several times in order to avoid passing vessels, she rolled tremendously on each occasion. She frequently rolled to the extent of 32 degrees both sides, and occasionally 40 degrees both sides was recorded, when her upper deck rails were under water. For thirty-six hours all hatches were battened down, except the torpedo hatch in the waist of the ship, and although this was the only means of communicating from below with the upper deck, it was found necessary to keep this hatchway covered with a hood. A large portion of the upper deck fittings and the gear stowed on the upper deck were torn from their fastenings and washed overboard, including an iron bin bolted to the fore barbette. This bin contained chains and other heavy gear weighing over two tons. Iron stanchions and rails were bent and broken by the seas, whilst the port cutter, which was topped and stowed amidships, had her bottom stove in. The lifebuoys and all the stern walk fittings were washed away. It was owing to the loss of a ventilator and the cover of a navel pipe that a large quantity of the water washed inboard, but as soon as an opportunity offered the ventilator hole and navel pipe were blocked up by shot stoppers. At one time the water in the ship was above the level of the stoke-hold plates, although four pumps had been kept continually at work. A rise of two feet more would have extinguished the furnace fires, and for this reason the vessel put back to Queenstown.

In answer to questions in Parliament respecting the statement made about her behavior during the gale, Sir U. Kay-Shuttleworth, Secretary of the Admiralty, said:

The *Resolution* had 787 tons of coal on board when leaving England and, steaming at 10 knots an hour, in fair weather she would have consumed 250 tons between the point where she turned back and her arrival at Gibraltar, leaving 280 tons on board on her arrival at Gibraltar. No injury was sustained by the ship so far as her structure was concerned, and there was no damage to fittings, so as to render her return to England necessary. All such defects could have been made good at Gibraltar, but the captain of the *Resolution*, in determining to put back, appeared to have been mainly influenced by anxiety about his coal supply in the event of the gale lasting many days, and in the exercise of his discretion he determined to proceed to Queenstown. At the time he altered the course for that purpose the vessel was distant 250 miles from Queenstown and 840 miles from Gibraltar. The Government did not propose to lay the report of Captain Hall on the behavior of the *Resolution* on the table. It had been ascertained that no accurate observations were made as to the extent of the rolling; the rail being under water would be a roll of 35 degrees in still water, but in a gale such as this a roll of less degrees would put the rail under water.

It was further stated that she had not been inclined since building, but that two other ships of the same class had been; that the maximum righting moment was at 37 degrees, and that the range of stability was up to 60 degrees.

It also transpired that the ships of this class were not fitted with bilge keels, owing to the fact that the present docks would not take one of them if she were so fitted.

The letter quoted on page 188 was forwarded to the "Times" by Admiral De Horsey, who spoke of the writer as an officer "scientific in a practical way." "Engineering," in a carefully prepared review of the letter and the general question of the stability of the ship, has this to say:

"It is not, of course, necessary to point out to those accustomed

to the design of ships that the qualities which tend to stability are, to a great extent, directly opposed to those which produce steadiness in a seaway, or freedom from rolling. To take an extreme example, a racing yacht—where everything is sacrificed to gain stability in order to carry a large sail plan—is an extremely uneasy vessel unless steadied by her canvas, and there was occasionally more fear of some of the old "lead mines" of five or six years back jerking their masts out than of carrying them away during a contest. In war vessels, where a steady gun platform is so necessary to efficiency, stability is deliberately sacrificed to steadiness. The metacentric height of the *Royal Sovereign* class is about 3½ ft., and the range of stability about 60 degrees.

"The fact is, naval officers have never yet quite unlearnt the traditions of the old sailing days; a fact well illustrated by the remarks of the officer 'scientific in a practical way,' already quoted. He says, 'Our maximum stability is 38 degrees, with a rapidly declining chance of righting until a vanishing point of 65 degrees is reached.' It may be true that the maximum righting moment is when the *Resolution* is inclined to about 38 deg., but chance of righting after inclination to that angle is not a rapidly declining one in a sailless ship. The rolling of a ship amongst waves is due to the impulses of the waves alone. Oscillation may be checked by other forces, but it is set up by the motion of the waves. The study of this subject is one of extreme interest and great complexity, as nearly all studies must be which include the action of waves. A few facts, however, may be worth putting forward at the present time.

"In the first place, it is not necessarily the biggest waves which produce the worst rolling effect. The scientific and practical officer before quoted expresses his dissatisfaction at finding the *Resolution* rolling 42 deg. each way in moderate weather directly she got into the Bay of Biscay, and we must say the fact was not reassuring, supposing the ship oscillated to that extent, a matter upon which we have considerable doubt, for reasons which we will explain later. Now, one of the most unpleasant features about modern ships is their 'natural periods.' The natural

period of vibration is an element with which engineers have been made painfully familiar of late, since quick-running engines have come into vogue, for when the period of the vibration of the ship synchronises with the strokes of the engine, the result is an enormous increase in the undesirable phenomenon. In the same way, every ship has a natural period of oscillation, and when this synchronises with the period of the waves to which she is subject, the one reinforces the other until the maximum rolling effect is produced. The matter may be illustrated by the case of a child in a swing. A slight push at the turn of each oscillation of the pendulum constituted by the swing will cause a wide range of movement; so, also, if there be synchronism between the wave impulse and the period of the ship, each wave tends to add to the range of oscillation, and, were it not for the beneficient action of fluid resistance, the vessel would be overturned. It is, therefore, evidently the object of the naval architect to so design his ship that there shall be least chance of synchronism, and for this purpose a long natural period is given, as it has been found that short periods of oscillation in still water (*i. e.*, short 'natural periods') tend to establish a fixed range of oscillation when the vessel encounters large ocean waves; for it may be remarked, although the biggest waves do not *necessarily* produce the worst rolling, yet it is the largest waves that have to be chiefly considered. Many illustrations of these statements have been recorded. For instance, it is stated in Mr. White's 'Naval Architecture' that vessels of the *Prince Consort* class rolled very heavily in an almost imperceptible swell, having a period just double that of the ship; whilst the *Achilles*, a very steady ship, rolled more heavily in an almost dead calm than she did in very heavy weather. Another instance quoted is that of the *Monarch*, which, when cruising with the combined squadrons in 1871, was said to surpass in steadiness most of the other ships in heavy weather, yet on one occasion rolled more heavily in a long swell than did the notoriously bad rollers of the *Prince Consort* class.

"The behavior of the *Devastation*, a ship with a double period of 13½ seconds, also quoted by Mr. White, is instructive. That vessel, when lying passively broadside on to waves, having a

period of about 11 seconds, rolled through the maximum angle of 6½ deg. to windward and 7½ deg. to leeward, making a total arc of 14 deg. When steaming in the same sea at 7½ knots, with wind and sea on her quarter, the total arc of roll was 27½ deg. The explanation is simple, although the facts are not in accordance with the general opinions of naval commanders. When in the trough of the sea, the period of the waves was less than the double period of the ship; but when the vessel steamed obliquely from the waves, their apparent period—or their period relatively to the ship—became increased so that they just equalled the period of the double roll of the *Devastation;* synchronism, and consequent accumulation of motion, thus being set up. The instances we have given and the facts set forth are all admirably treated in Mr. White's book, to which naval officers might evidently more often turn with advantage. If we have succeeded in making ourselves clear, it should be plain to all scientifically practical naval officers what the difference is in regard to the chance of recovery, between a ship hove down by wind pressure on her sails, and one rolling to an equal angle simply by the impulse due to wave motion. In the former case the heeling force is continuous, in the latter it is transitory.

"The naval officer usually has recourse to the pendulum when he wishes to ascertain the angle of heel of his ship, and for this he is not to blame, for faulty as the instrument is, it is probably a trifle more reliable than his own sensations, and other more trustworthy instruments are not readily available. The sources of error in pendulum instruments, or clinometers, are well known. If the instrument by which the angle of roll of the *Resolution* was taken were high up above water, probably 30 ft. or more above the center of gravity of the ship, we can easily credit it registered 45 degrees of heel, even though the deck line of the ship may not have gone below water. When a ship rolls she turns about a longitudinal axis, and if the point of suspension of the pendulum does not coincide with that axis, being either above or below it, the weight will manifestly be subjected to angular acceleration. When the further disturbing influence of the ship rising and falling amongst waves is added, the defect is greatly in-

creased, and an error of over 100 per cent. has been more than once recorded of pendulum observations. Unless we hear that more accurate means were had recourse to for registering the angle of roll of the *Resolution*, we shall feel justified in taking a very large discount off the statements made as to the extent of rolling.

"Forty feet is said to be a low estimate for the height of the waves encountered. Probably very few persons, even naval officers, recognize what a vast mass of water a 40-ft. wave is. An Atlantic wave of that height would probably be 800 ft. to 1,000 ft. long. We believe there is no trustworthy record of waves over 48 ft. in height, but there are many instances of waves having been met that have been estimated at 100 ft., probably far more. Of course 40 ft. may have been, as said, a low estimate of the waves encountered by the *Resolution*, but there is nothing more difficult than the judging of the height of waves. Few who have not been in the habit of verifying their sensations by scientific observation know what a very respectably rough sea a series of 15-ft. waves will constitute. The officer in question appears to have founded his estimate on the height (37 ft.) of the fore bridge, where he was standing. An observer stationed at such a height from the center of gravity of a ship rolling 45 deg. might easily add 25 or 50 per cent. to the height of a wave without doing any violence to his conscience. The great difficulty in observations of this nature is to obtain a true vertical, and often when the investigator fancies he is looking in a horizontal direction, he is peering towards the depths of the ocean at a pretty considerable angle.

"To sum up the view we take of this matter, we would say that, though the *Resolution* undoubtedly passed through exceptionally bad weather, the statements as to her behavior are not proved by the facts brought forward; but even if she rolled 45 degrees each way, she had still a fair margin of safety before she reached the point of vanishing stability at 60 degrees heel. We would, however, be far from saying that her captain was ill-advised in using the discretion vested in him and returning home to refit. With his upper works damaged, and a ship newly com-

missioned with a strange crew, who appear, however, to have behaved admirably under what were certainly very trying circumstances, the step may have been a wise one, though certainly not to be defended on the score of shortness of fuel, one of the reasons advanced. The little torpedo gunboat *Gleaner* got through safely, and without doubt the *Resolution* would have done so also had she been put to it. Whether it would have been wise to put her to it is quite another matter; for our ships are so designed that they remain seaworthy long after they have ceased to be safely habitable. The statements as to rivets leaking, &c., have been contradicted on good authority, and the large quantity of water that got below was apparently due to deck openings not being properly secured at first."

Sir E. J. Reed also came forward, and in a letter to the "Times" stated that the *Resolution* and the other ships of her class have ample stability. As he has never failed to criticise a design which he considered faulty, his opinion did more to allay the apprehensions on the subject of want of stability than all the official assurances that were made.

Her repairs were completed at Plymouth, whence she sailed on the 12th of January for Vigo, where she joined the Channel Squadron on the 15th.

The "Naval and Military Gazette" says that it has transpired, with reference to the vessel's defective torpedo tubes, that whilst a party of men were engaged in working the submerged torpedo tubes the sluice-valve door of the port tube could not be closed owing to the locking bar having become broken. As the fittings are twenty feet below the water line, the water rushed into the tube, forced through the stop bolt, and emptied itself into the submerged tube compartment. The inrush of water was stopped by placing a collision mat over the outer aperture and securing it with screwed stoppers. It was then discovered that the locking bar of the starboard tube was also damaged, and this tube was treated in the same way as the opposite one. With this temporary repair the torpedo tubes are perfectly useless, and as it would be necessary to dock the vessel in order to effect a sat-

isfactory repair, it is difficult to understand why the work is not carried out before again sending the ship to sea.

Barfleur.—Sister ship to the *Centurion*, described on page 1044 of volume V of the JOURNAL, was tried under natural draft on the 9th, and under forced draft on the 14th of November, with the following mean result:

	Natural Draft.	*Forced Draft.*
Mean draught of water, feet and inches	23–6	23–9
Displacement, tons	9,500	9,650
Steam pressure	148.5	142.4
Air pressure	.....	.....
Revolutions	95.6	105.2
I.H.P.	9,894	13,163
Speed by patent log	17.165	17.537

The ship was thus two feet light on the first, and 21 inches on the second trial.

Sanspareil.—A sister ship to the unfortunate *Victoria*, is at Malta, having six bulkheads put in on her main deck, which leads to the conclusion that, in spite of Mr. White's assurance of the sufficiency of the water-tight subdivision of the *Victoria*, the British Admiralty has recognized points of weakness in it.

Powerful and *Terrible.*—These vessels are intended to be the largest and fastest cruisers afloat. They are 500 feet long, 71 feet beam, 27 feet draught, of 14,200 tons displacement, and will be wood sheathed and coppered. The bunker capacity is 3,000 tons, 1,500 of which are to be carried on the above draft of 27 feet. They are known as "commerce protectors," and therefore do not carry a very heavy battery for their size. They will have two 9.2-inch, one at bow and one at the stern; twelve 6-inch; eighteen 12-pounders, and twelve 3-pounders, besides a number of machine guns, and four submerged torpedo tubes. The protective deck will be four inches thick over machinery and magazines, and reduced to two inches at the ends.

The machinery will consist of four sets of triple-expansion engines, operating twin screws, designed for 25,000 horse power. The boilers will be of the Belleville type, forty-eight in number, arranged in eight compartments, and will have 2,840 square feet of grate and 67,790 square feet of heating surface. From the

usual output of the Belleville boiler, the number in this design should furnish steam for 30,000 instead of 25,000 horse power.

The speed expected of these ships is upwards of 20 knots continuously at sea, 22 knots on an eight-hour trial with natural draft, and 24 knots on the four-hour forced-draft trial.

The machinery for the *Powerful* will be built by the Thomsons, of Clydebank, who built the *Paris* and the *New York*, and that for the *Terrible* by the Naval Constructions and Armament Company.

St. George.—First-class sheathed cruiser of 7,700 tons displacement, built and engined by Earle's Shipbuilding Co. She is 360 feet long, 60 feet 8 inches beam, and 24 feet 9 inches mean draught. She has twin-screw, triple-expansion engines, with cylinders 40, 59 and 88 inches diameter, and 51 inches stroke, designed for 12,000 I.H.P. at full power. The condensing surface in the main condensers is 13,500 square feet, besides which there is an auxiliary condenser. There are four double-ended boilers 16 feet diameter and 18 feet long, containing thirty-two furnaces, each 42 inches diameter, and one auxiliary three-furnace boiler 12 feet 6 inches diameter, and 9 feet 8 inches long, all designed for a working pressure of 155 pounds. The total grate is 855, and the heating surface 25,000 square feet. The shell plates of the large boilers are $1\frac{3}{16}$ inches thick. Her screws are 16 feet 1 inch in diameter.

The armament is the same as that of the other vessels of this class, viz: two 9 2-inch, ten 6-inch, twelve 6-pounders, five 3-pounders, seven Nordenfelts, and four torpedo tubes.

Her natural-draft trial gave the following results:

Mean draught (3 feet 6 inches light), feet and inches	21–3
Steam pressure	153.8
Air pressure	.09
Revolutions	100.
I.H.P.	10,536.
Speed by patent log	20.2

Theseus.—First-class cruiser, described on page 1049, of volume V, recently completed her trials with the following results:—

Mean draught ($5\frac{1}{2}$ inches light), feet and inches	23–$3\frac{1}{2}$
I.H.P	10,608.
Speed by patent log	18.66

Her first trial was unsuccessful on account of the boilers priming.

Astræa.—The trials of this second-class cruiser, described on page 518, of volume V, were made on the 27th and 30th of December, with the following results:

	Natural Draft.	*Forced Draft.*
Steam pressure	147.	149.
Air pressure	.....	1.44
Revolutions	130.65	138.3
I.H.P.	7,600.	9,112.
Speed by patent log, knots	19.	19.75

Speedy.—This vessel differs from the other torpedo gunboats of the British Navy principally in the machinery, the guarantee in her case having been 4,500 instead of 3,500 horse power. The engines are vertical, twin-screw, triple-expansion, with cylinders 22, 34 and 51 inches diameter, and a stroke of 21 inches. The boilers are of the familiar Thornycroft type, eight in number, designed for a working pressure of 200 pounds, and have a combined grate surface of 204 and heating surface of 14,720 square feet. The propellers are three-bladed, 8 feet 3 inches in diameter. The weight of machinery is about 210 tons, 73 of which are engine-room weights.

Her trials were run during the latter part of October and the first of November, the forced-draft one having been twice unsuccessful, the first time on account of a hot crank pin, necessitating her return under one engine, and the second on account of a leaky condenser. The final trial was run during heavy weather, and in comparatively shallow water. The following are the results of the several trials:

Duration of trial, hours	8.	2.	2.	3.
Steam pressure	183.	190.	200.	194.
Air pressure	.58	1.25	...	1.7
Revolutions per minute	206.4	...	245.	245.
I.H.P.	3,043.	4,390.	4,646.	4,675.
Speed by log	18.5[1]	20.4	21.0	20.0[2]
[1]Mean draught, feet and inches				9–8½
[2]Mean draught, feet and inches				9–7

The details of the final official trial are:

	Starboard.	*Port.*
Revolutions	247.	243.
I.H.P., H.P	748.5	759.2
I.H.P., I.P	795.1	762.7
I.H.P., L.P	846.7	762.5
I.H.P., total	2,390.3	2,284.4
I.H.P., collective	4,674.7	

The speed with one engine, after the second trial, was 11 knots.

Antelope.—The trials of this torpedo gunboat have been recently completed. Two of her trials were interrupted by casualties, the first by the splitting of a feed pipe, and the next by priming of the boilers. On her successful natural-draft trial, with one-half inch air pressure, she developed upwards of 2,500 horse power on about 220 revolutions, and made over 17 knots in a heavy sea. The results of the three-hour forced-draft trial were

Steam pressure	140.	
Air pressure	1.35	
Revolutions	243.3	246.8
I.H.P.	1.838.	1,783.
Total	3.621	
Speed by log, knots	19.	

Jason, *Jaseur*, *Circe*, *Alarm*, *Leda*, *Hebe*, *Onyx*, *Renard* and *Antelope.*—These are the other torpedo gunboats, which differ from the *Speedy* mainly in the boilers, and in the details of the engines due to the practice of different builders, those of the three first having been built at Barrow; of the next three, by Penn; of the *Hebe*, at Sherness dockyard; those of the *Onyx* and *Renard* by Laird, and the *Antelope's* by Yarrow.

The vessels are 230 feet long, 27 feet beam, and were designed for 810 tons displacement on a draught of 8 feet 9 inches. They have a raised forecastle extending about one-third their length and a flush deck abaft it. They have two pole masts and two smoke pipes.

The armament consists of two 4.7-inch and four 3-pounder rapid-fire guns, and three 18-inch torpedoes, one fixed in the bow and two swivelling in broadside.

The engines are the same size in all, 22, 34 and 51 by 21 inches stroke, and weigh about 55 tons. The boilers, four in number, designed for a working pressure of 155 pounds, are of the wet-bottom locomotive type, each boiler having two furnaces, with a water wall between, as shown in outline sketch of the *Jason's* boiler, opposite page 616 of volume V of the JOURNAL. The grate and heating surfaces differ slightly in the different vessels, running from 163 and 6,163 in the *Hebe* to 182 and 6,388 in the *Jason*. The boilers weigh about 96 tons, and the water in them 30, while the total fire-room weights are 155 tons. The propellers are 8 feet 3 inches diameter and 9 feet 4 inches pitch.

The trial results of this class were:

	Revolutions.	*I.H.P.*	*Speed.*
Jason	...	3,552	19.
Jaseur	.....	3,711	19.
Niger	255.9	3,786	19.3
Circe	249.	3,508	19.3
Alarm	262.5	3,886	19.2
Leda	246.	3,597	18.3
Hebe	245.6	3,566	19.0
Onyx	.....	3,548	19.0
Renard	254.	3,962	19.4
Antelope	240.	3,621	19.0
Speedy	245.	4,675	20.0

The mean draught of the *Hebe* was 9 feet 9 inches, and of the *Speedy* 9 feet 7 inches. Others not given. The *Hebe* was subsequently tried with greater air pressure, that used in the trial above recorded having been 2 inches.

The results were:

Mean draught, feet and inches	9–9½
Steam pressure	142
Air pressure	3.7
Revolutions	251.2
I.H.P.	3,936

Of this trial, "Engineering" says:

Perhaps the most instructive part of this latter trial is the great additional air pressure for draft required to give another 400 indicated horse power. On the official trial the air pressure was but 2 ins., but on the later trial no less than a mean of 3.7

ins. was required. The reason is instructive. The tubes of the *Hebe's* boilers were fitted with the Admiralty ferrule. This is a device in which the joint of the tube end with the tube plate is protected by a trumpet mouth, which projects out of the tube and turns back on the plate. As there is an air space between the tube plate and the turned-over end of the ferrule, the latter naturally must get red hot, at any rate, when the boiler is forced to any extent. However this may be, there is no doubt that ferrules of this type conduce to that very unpleasant boiler disease known as "bird's-nesting." A "bird's nest," it may be stated for the benefit of those who have not had experience in this direction, consists of a built-up obstruction of small particles of coke or coal. The first thing that happens is that a ring of these particles forms round the crown of the trumpet-mouthed ferrule. This annulus gradually grows inwards across until, in extreme cases, the ferrule mouth becomes entirely closed by a disc of coke-like substance. The mass does not grow up inside the tube, but simply extends across it, forming not a lining, but a lid. In the case of the *Hebe*, after her extra forced-draft trial, in one boiler 10 per cent. of her tubes were, we believe, practically entirely closed. The bird's nest is of so firm a texture that it may be removed bodily, and the various stages of formation are extremely interesting. Judging from examples of bird's nests taken from the *Hebe*, we doubt very much if she could have continued running at the power she did for much longer. That, however, is a matter of opinion, but the boilers were working with 6-in. air pressure at the finish. Of course bird's-nesting is no new thing, it having been a matter with which torpedo-boat builders have long been acquainted. The formation of the foundation ring of the nest in bell mouthed ferruled boilers, is generally attributed to the fact that the ferrule gets red-hot, and it is a curious speculation how near the tube plates and tube ends of torpedo-boats' boilers—on which bird's nests have formed—may have arrived to that state. Doubtless a tube plate cannot get red hot when one side of it is in contact with water, but the question is, actually, how near is the water?

Sharpshooter.—This torpedo gunboat, whose trials a few years

ago were such a failure as to cause the Admiralty to reduce the requirements of the other vessels of her class from 4,500 to 3,500 horse power, has had her locomotive boilers removed and Belleville boilers substituted. The new boilers have 269 square feet of grate and 7,696 of heating surface.

The *Spanker*, another vessel of this class, has had her locomotive boilers removed, and will be fitted with Du Temple boilers.

Alert and *Torch*.—Two new sheathed gunboats, from the designs of Chief Constructor White, are to be built at Sheerness. Their principal dimensions are—

Length on water line, feet	180
Beam, feet and inches	32–6
Draught, mean, feet and inches	11–6
Displacement, tons	960

The upper and lower bunkers of the ships will be separated by a light steel water-tight deck of $\frac{3}{8}$-inch plating. The shell is to be of 10 pound plating, covered with teak $3\frac{1}{2}$ inches in thickness to a height just above the water line. The stem and stern posts are to be of phosphor bronze.

The engines will be triple-expansion of 1,400 I.H.P. under forced and 1,050 under natural draft, giving a speed of $13\frac{1}{4}$ and $12\frac{1}{4}$ knots, respectively.

The armament will consist of six 25-pounders and four 3-pounders—all rapid-fire guns.

Havock.—Further details of this remarkable little craft described on page 1,056 of volume V, show that she is 180 feet long, $18\frac{1}{2}$ feet beam, 6 feet draught, with a displacement of 215 tons, and that she has no less than twenty water-tight compartments. In appearance, she is not unlike a torpedo boat, except that her forecastle (turtle back) is much higher, rising above the main deck, and affording the principal berthing space for the crew. She has one signalling mast, and two smoke pipes. Her armament comprises one 12-pounder on the forecastle, three 6-pounders, and three 18-inch torpedo tubes, one fixed in the bow, and two swivelling in broadside. She has twin-screw, triple-expansion engines, 18, 26 and $39\frac{1}{2}$ by 18 inches stroke, each engine having

its own condenser and circulating pump. Steam at 180 pounds pressure is furnished by two locomotive boilers with copper fire-boxes, having 100 square feet of grate, and about 5,000 of heating surface. Piston valves are fitted to all the cylinders. The machinery occupies 76 feet in the length of the boat, and the officers' and artificers' quarters 30 feet. Her complement is three officers and forty-two men.

On her official trial, she made 26.783 knots as a mean of four runs over the measured mile, the engines making 362 revolutions and developing 3,400 I.H.P., with a steam pressure of 165 pounds, and an air pressure of $2\frac{1}{8}$ inches in the fire room; and $26\frac{1}{8}$ knots for three hours.

Her bunker capacity is 60 tons, and on the official trial the weight carried was 35 tons.

Daring.—This twin-screw torpedo-boat destroyer, whose boilers are described on pages 156 to 161, was launched by Messrs. J. I. Thornycroft & Co. on the 24th of November last. Her principal dimensions are:

Length, feet	185
Beam, feet	19
Draught, mean, feet	6
Displacement, tons	220

Her engines are of 3,500 horse power, with which she is expected to make 27 knots. They are of the triple-expansion type, with four cylinders, the high-pressure being 19, the intermediate 27, and the two low-pressure 27 inches in diameter, the stroke of the pistons being 16 inches.

The boilers are three in number, of the new Thornycroft type, and have been designed for a working pressure of 210 pounds. The grate surface is 189, and the heating surface 8,892 square feet. Her armament consists of one 12-pounder rapid-fire, forward, and three 6-pounders, two forward and one aft.

FRANCE.

Duchayla, *Cassard* and *D'Assas*.—These are three new cruisers under construction, designed for a speed of 19 knots. Their principal dimensions are:

Length between perpendiculars, feet	325.6
Beam, feet	44.9
Depth, feet	29.8
Draught, mean, feet	19.0
Displacement, tons	3,888

They have a protective deck 1.2 inches in thickness at the center and 3.15 on the slope.

There are two vertical triple-expansion engines, designed for 6,000 I.H.P. with natural, and 9,000 under forced draft. Steam is supplied by twenty d'Allest boilers placed in three compartments.

The armament consists of six 16-cm., four 10-cm., twelve 47-mm. rapid-fire guns, six 37-mm. revolving cannons, and six torpedo tubes.

Catinat.—A sheathed cruiser, to be built by the Forges et Chantiers de la Mediterranée, to make 19 knots.

Length between perpendiculars, feet	328.75
Beam, feet	41.33
Depth, feet	30.50
Draught, mean, feet	19.68
Displacement, tons	3,934

Her protection embodies a new feature in warship construction, the protective deck, one inch thick on the flat and from one to one and a half on the slope, having some distance below it a second deck from $\frac{5}{16}$ to $\frac{7}{16}$ inch thick, the combination being deemed necessary on account of the destruction that might be wrought by melinite shells, experiment having shown that the plan here fitted will prove effective in preventing destruction of the parts below the lower deck. The conning tower is four inches thick.

She will have vertical, triple-expansion engines, designed for 7,000 I.H.P. with natural, and 9,000 with assisted draft. The boilers are of the Belleville type.

The armament consists of four 16-cm., ten 10-cm., fourteen 47-mm. and four 37-mm. guns, and six 14-inch torpedo tubes.

She will have two military masts each with two fighting tops.

Surprise.—A single-screw, sheathed gunboat, designed by M. Normand. She will be bark rigged, and spread about 12,000 square feet of canvas.

Length between perpendiculars, feet	183.67
Beam, feet	24.60
Depth, feet	13.90
Draught, mean, feet	10.12
Displacement, tons	616

The engine is vertical, triple-expansion, with four cylinders, and is designed for 650 I.H.P. with natural and 850 with forced draft, the speed expected under the latter condition being 13 knots.

Her armament will be two 10-cm., four 65-mm. and four 47-mm. rapid-fire guns.

Casabianca.—A torpedo chaser, designed for 21.5 knots, is of the following dimensions:

Length, feet	262.50
Beam, feet	27.30
Draught, mean, feet	10.25
Displacement, tons	928

She will have twin-screw, triple-expansion engines of 5,000 I.H.P., and eight boilers of the d'Allest type arranged in two compartments.

Her armament will be one 10-cm., three 65-mm., five 47-mm. and four 37-mm. rapid fire guns, and three torpedo tubes.

Lansquenet.—A torpedo boat destroyer, of 170 tons displacement, built by M. Oriolle, and guaranteed to make a speed of 26 knots. She has two 18-inch tubes, one forward intended for ahead fire and capable of being trained through an arc of 30 degrees, and the other one well aft, besides two 47-mm. rapid-fire guns.

Her motive power consists of two three-cylinder, triple expansion engines of 2,000 I.H.P. each, to which steam is supplied by four Oriolle boilers in two water-tight compartments. The condensers and auxiliary machinery are in a separate compartment abaft the engines. In order to equalize the weight of the reciprocating parts, the intermediate and low-pressure pistons have been made of aluminum.

The four boilers contain 143.4 square feet of grate and 5,920 of heating surface. There are three smoke pipes. Forced-draft

fans have not been fitted, the design being to use a steam jet when running at full speed.

Her trials have already commenced, and, with two boilers and natural draft, she made 16 knots with 202 revolutions of the engines.

There is a clause in the contract for her construction imposing a penalty of 6,000 francs for each tenth of a knot below 26 between 26 and 25 knots, and of 4,500 for each tenth below 25 between 25 and 24 knots. Above 26, there is a premium of 7,000 francs for each tenth between 26 and 27 knots, and of 8,000 above 27.

ITALY.

Re Umberto.—The final trials of this battle ship were made on the 25th of October last, and were highly successful. The contract stipulated for the development of 15,200 horse power natural draft and 19,500 forced draft, but as hereafter shown, the Government decided to abandon the forced-draft trials. The run was made from Spezia to Genoa and back, a distance of 120 knots, at an average speed of 18.3 knots, the engines indicating a mean of about 17,000 horse power on 95 revolutions, with $\frac{1}{4}$ inch of air pressure in the stokeholds. The maximum power during the run was found to be 19,000 horse power, and the maximum speed 18$\frac{1}{2}$ knots, which was obtained by only $\frac{1}{2}$ inch of air pressure. The machinery worked smoothly in every respect, no water service being used. The boilers gave a plentiful supply of steam without priming or other difficulties. The results were considered so satisfactory from every point of view, both as regards the speed of the vessel and the facility with which the speed could be maintained (the trial being made by the ordinary ship's crew and not by special stokers), that the commission appointed recommended the Marine Ministry to accept the machinery without further trials, as it appeared so obvious that the horse power with forced draft would largely exceed the contract power of 19,500 horses. The recommendation was, therefore, accepted by the Ministry of Marine. This powerful ironclad is fitted with four 34-centimeter 67-ton Armstrong guns,

eight 15-centimeter guns, sixteen 12-centimeter, ten 5.7-centimeter, and seventeen 3.7-centimeter quick-firing guns, and two machine guns. The dimensions of the ship are as follows: Length, 400 feet; beam, 76.9 feet; draught, 28.6 feet; displacement, 13,250 tons,

Aretusa.—Torpedo gunboat, built for the Italian Government by Orlando Brothers, Leghorn. The following description of the vessel, her machinery and her trials is from "Engineering" of December 22, 1893, which also gives indicator diagrams and illustration of the engines.

The *Aretusa* is 230 feet long by 25 feet 6 inches beam, and at 11 feet 9 inches draught displaces 740 tons. Her armament consists of one 12-centimeter gun, six 6-pounders and three 3-pounder quick-firing guns, and three machine guns. She can launch five torpedoes simultaneously.

The engines are triple-expansion, with cylinders 23.23, 36.18 and 54.13 inches diameter by 18.11 inches stroke, working with a boiler pressure of 170 pounds. The engines are placed in two separate compartments, the reversing and starting gears being in the center, and the condensers placed at the sides of the ship. Each condenser has 1,787 brass tubes .63 inch in diameter, with a condensing surface of 2,551 square feet. The condensing water is driven through the condensers by two centrifugal pumps, the suction and discharge pipes being 9.84 inches in diameter. The condensers are made entirely of delta metal. The feed and bilge pumps are of the Worthington modified pattern, and their working was very effective during the whole of the trials, and also when the vessel was under steam in commission.

The low-pressure slide valves are fitted with Joy's assistant cylinders, this being their first application in Italy. Each of these developed during the trials 8 to 10 indicated horse power. The slide valve and rod weigh 718.7 pounds. The low-pressure eccentrics worked smoothly, and did not show any indication of heating at a speed of 270 revolutions.

The boilers, four in number, of the open-bottom locomotive type, are placed two forward and two aft of the engines, the former supplying the port and the latter the starboard engines. The

total heating surface is 8,417.68 square feet, and the fire-grate surface about 185½ square feet. The air blast is delivered under the grates through a closed ashpit, each pair of boilers having its own funnel of 63 inches diameter. The boilers proved very satisfactory. No leakage, priming or other defect was noticed under natural or forced-draft steaming.

The propellers' bosses are of gun metal, with blades of Stone's patent bronze, the diameter being 8 feet and the pitch 9 feet.

The total weight of engines, boilers, water, spare pieces, &c., is 173 tons, making about 86 pounds per indicated horse power.

Under the contract two trials were to be made, one of ten hours' duration under natural draft, the power developed to be not less than 2,000 indicated horse power, and a three hours' trial under forced draft with an indicated horse power of not less than 4,000. A premium was to be paid for extra power developed in the forced-draft trial. The natural-draft trial was made on September 22, 1892.

The weather was fine, with a slight northwest wind blowing. The trial commenced at 6·15 A. M., the engines being under full steam at about 230 revolutions per minute with natural draft. The ship started opposite the Meloria Tower. The mean average of the revolutions indicated by the continuous recording apparatus for the ten hours was, for the port engine, 218.7 revolutions, and for the starboard engine, 218.5 revolutions. During natural-draft trials it is allowed in the Italian navy to run the fans to assist the ventilation, but not to give any air pressure in the stokeholds. This time the fans were not put in motion during the trial, as the contractors did not consider it necessary. The distance of 72 miles from the Meloria to Nervi, in the Gulf of Genoa, was run in 3 hours 59 minutes, giving a mean speed of 18.06 knots. The ship was then turned and put on her return course, completing her trial at 4·15 P. M., south of Leghorn, without a single hitch during the whole of the ten hours' run. The mean indicated horse power for the ten hours was 2,129, being 129 over the contract. The vibration of the hull was very slight.

The diagrams taken from the Joy's assistant cylinders gave a collective indicated horse power of 13.08. The working of the

main engines was very satisfactory and noiseless, without heating or trouble.

The forced-draft three hours' trial was also successful. The contract power to be obtained on this trial was 4,000 horse power, but this was exceeded by 422, the mean indicated horse power for the three hours being 4,422, with a mean of 264 revolutions per minute for the starboard engine and 265.23 for the port engine. The assistant cylinders gave 16.80 indicated horse power, this power being added to the power developed by the main engines. Diagrams were taken every quarter of an hour. The mean indicated horse power being 422 over the contract, the maximum of the premium, about £5,000, has been paid to the firm. The highest number of revolutions per minute, reached several times during the trials, was 269 for the starboard engine and 270 for the port. The approximate maximum power reached was nearly 4,800 indicated horse power. A mean speed of 20.70 knots was obtained during the three hours' trial. There was rain and wind blowing strongly from the southwest toward the finish of the trial.

On the same day, before starting the official trial, curves were taken to show the vibrations under different speeds. The greatest vibrations were observed at a speed of from 230 to 240 revolutions, while at a higher speed the vibrations diminished. On the preliminary trials, however, the vibrations were very remarkable. In order to obviate this, the constructors decided to change the low-pressure pistons. The original low-pressure pistons were of the usual form, with cast-iron rings similar to those of the high and intermediate cylinders, and weighed each 540 kilogrammes (1,190½ lbs.). They were changed for new pistons with brass rings, each weighing 430 kilogrammes (948 lbs.). The result was a decided improvement, as it diminished the vibrations in the hull, and allowed the engines to be run at their very high power without the slightest trouble.

RUSSIA.

Admiral Oushakoff.—A coast-defense vessel was recently launched. She is 278 feet long, 52 feet beam, 17 feet draught,

and of 4,126 tons displacement. Her side armor is 10 inches thick, and her armament consists of four 10-inch rifles, twenty rapid-fire guns, and torpedoes.

She has twin-screw triple-expansion engines of 5,000 I.H.P., steam for which is furnished by four single-ended return tubular boilers. The designed speed is 16 knots. She stows 200 tons of coal.

Three Saints (*Tri Sviatitelia*).—A battle ship belonging to the Black Sea fleet has been launched at Nicolaieff. She is 357.5 feet long, 72.2 feet beam, 27.5 feet draught, and of 12,480 tons displacement. Her side armor is 16 inches thick. She carries four 12-inch, eight 6-inch, and four 4.7-inch guns, besides a number of smaller ones and an outfit of torpedo tubes.

Her machinery has been built by Humphrys and Tennant, London, and the engines are of the same size as those of the ill-fated *Victoria*—43, 62 and 96 inches diameter of cylinders by 51 inches stroke, designed for 10,600 I.H.P. under natural draft, with a piston speed of 700 feet per minute. The condensers are rectangular in section, and form the back framing of the low-pressure cylinders. They have a total cooling surface of 18,500 square feet. The boilers are in four water-tight compartments. There are fourteen single-ended ones, each with three 50-inch furnaces, having a combined grate and heating surface of 1,050 and 31,024 square feet, respectively, and two auxiliary boilers 9 feet 4½ inches diameter and 8 feet 3 inches long, containing 44 square feet of grate and 1,084 square feet of heating surface. The boiler tubes are 3 inches in diameter. It is thus evident that this vessel will not be deficient in boiler power, and that with forced draft, for which eight 78-inch fans have been provided, she should be able to develop 15,000 horse power with ease and make at least 18 knots, unless the large furnaces cause trouble.

The screws are 17 feet diameter and have adjustable blades, the pitch of which can be varied from 22 to 25½ feet.

MERCHANT STEAMERS.

Northwest.—This steamer, a description of which was given on page 238 of volume V, was launched at the Globe Iron Works, Cleveland, on the 6th of January. As a more extended description of her is now at hand, the data heretofore given is reproduced, together with the additional information.

The general dimensions are are as follows:

Length over all, feet	383
Length between perpendiculars, feet	360
Breadth, molded, feet	44
Depth, molded, feet	26
Depth to spar deck, feet and inches	34–5

She has been built of mild steel throughout, with an inner bottom extending from the collision bulkhead forward to the afterpeak bulkhead aft. She has been built under special survey in order to obtain the highest classification in the United States Standard Rules. The hull has been specially strengthened and subdivided through transverse and longitudinal bulkheads into numerous water-tight compartments, several of these bulkheads extending to the spar deck, without any doors or openings cut through, and where it has been found necessary to have passages through the bulkheads specially-designed water-tight doors have been fitted which can readily be closed in case of emergency. The construction throughout has been planned and carried out with the view of making the *Northwest* not only the most modern and luxurious, but also the strongest and safest conveyance on the lakes.

The design of the hull is a novel departure from the system generally used for high-speed merchant steamers, as, instead of carrying the after lengths of the shafts through the ship's sides, and consequently have them exposed and unsupported for a considerable length, the hull in this case has been constructed around

the shafts in such a way as to give not only great strength to the after body of the vessel, but also to form as little resistance as possible and allow the water to pass freely to the wheels. The same system of construction has been used in several of our cruisers.

The interior of the hull has been constructed to meet the requirements necessary for the Belleville boilers, which are placed about amidships in three separate water-tight compartments. Alongside of the thwartship stokeholds are the coal bunkers, which extend longitudinally through the different boiler spaces, and are capable of holding 1,000 tons of coal. The arrangements for coaling have received special attention, and in order to reduce the time necessary for that purpose to a minimum the coaling hatches have been trunked in, and the bottom of each trunk formed into four sloping coal chutes, each leading into a different coal bunker; the coal being thus directed in its fall will spread itself uniformly over the bunkers, thereby obviating the necessity of trimming the coal to any great extent.

Forward of the boiler rooms is a cross bunker for a reserve supply of coal, and a tunnel through this cross bunker leads into the space in which the refrigerating machinery, freezing tank, water-pressure tanks and other auxiliary machinery is placed.

The hold forward is subdivided into trimming and supply-tank and cold-storage provision rooms.

An elevator is fitted at the after end of the provision rooms, communicating with the main deck, on which the galleys, pantries, dining and mess rooms are located.

There are two vertical, quadruple-expansion engines of 3,500 horse power each. The sizes of the cylinders are 25 for the high, 36 for the first intermediate, 51½ for the second intermediate and 74 for the low-pressure, with a stroke of 42 inches. Piston valves are used on all of the cylinders; one for the high, two for the first intermediate, two for the second intermediate and two for the low-pressure, arranged outboard on the working side. All are operated by the Joy valve gear and reversed direct by steam and hydraulic gear. The reverse arms are slotted and are fitted with blocks and adjusting screws. The engine columns on the

back or inboard side are of cast iron, forked and of box section, and are braced together by cast-iron flanged distance pieces. The columns are fitted with detachable water-back guide faces. The front columns are of turned wrought iron, to which are attached by brackets the reverse shaft and link for the valve gear. The cylinders are without jackets or liners, and the valve chests are connected by faced joints and turned bolts. The L.P. and second I.P. cylinders are fitted with cone-shaped disc steel pistons, and the first I.P. and H.P. cylinders have cast-iron pistons, all of which are fitted with followers and single-ring packing set out with flat bent springs. The piston rods are of steel, but do not extend through the top cylinder head and are secured to the piston head by quick taper and nut. The lower end is fitted with bolts and brasses that connect to pin in upper end of the connecting rod.

The crosshead, which is of the slipper pattern, of cast iron, is fitted with adjustable brasses and bolted to the piston rod. The connecting rod is of reforged iron, the lower end T-shaped and fitted with brasses, lined with Babbitt and secured to the rod by bolts and plate. In the middle of the rod jaws are forged on and slotted out to receive the brasses, to which is connected the vibrating lever of the valve gear. The upper end of the rod is forked and fitted with the steel pin that engages the crosshead as already described.

The bed plate is of cast iron, in four sections, planed and bolted. The main journals in the bed plate are bored out and faced at end. Brass bushes, without flanges and Babbitted, are fitted top and bottom alike, and secured in place by cast-iron liners and bolts. The crank shaft is of wrought iron, built up in four duplicate interchangeable parts, 13½ inches diameter, and crank pin 14 inches diameter by 16 inches long. The crank shafts have solid forged couplings fitted with straight turned bolts. The total bearing in the bed plate is 10 feet 8 inches. The thrust block is of the horseshoe type, with cast-iron shoes and faced with Babbitt, the sole plate being bolted to the bed plate. Intermediate bearings, lined with Babbitt metal, are placed at proper intervals to support the intermediate shaft.

The screw propellers are four-bladed, sectional, 13 feet diameter and 18 feet pitch. The blades are of cast iron.

Each engine has an independent air pump run by a vertical, compound, direct-connected engine. The cylinders are 15 and 30 inches diameter, with a stroke of piston of 18 inches. The air pumps are single acting, 38 inches bore by 18 inches stroke. The condenser is bolted on the side of the channel plate and is fitted with cone and spray nozzle, injection valve, etc. The feed pumps will be placed in the fire rooms. The cold-water, bilge and sanitary pumps are of vertical duplex type, and are located in the engine room.

The engines when turning 120 revolutions per minute will indicate 3,500 horse power each, and with a total horse power of 7,000 the vessel is expected to make an average speed of over 20 statute miles per hour.

The boilers are the Belleville patent water-tube system. Their nominal evaporative efficiency will give the main engines 7,000 horse power and to the auxiliaries 500 horse power more, with natural draft. The boiler power is divided into three groups of generators. Each group is inclosed between athwartship and longitudinal bulkheads. There are two groups of ten and one group of eight generators. Each group has its own smokestack, so that the vessel will be a 3-pipe boat. Each group has two fire rooms, connected by a cross passage. The generators are placed back to back over the keel and the fire rooms are outboard of them; therefore there are the boilers in the center of the vessel, the fire rooms outboard of the boilers, and the bunkers outside of all. Thus, the boilers are 12 feet 9 inches athwartships, from face to face, and the fire rooms 6 feet 7½ inches each. The outer limits of fire rooms are the fore and aft bunker bulkheads, which are 26 feet apart, leaving bunker space on each side of vessel at the widest part of 9 feet. The bunkers will store about 1,000 tons of coal.

The three groups of generators, the cross passages and fire rooms will occupy a floor space of 26 feet wide by 124 feet long. The total grate surface is 812 square feet; total heating surface, 22,736 square feet; total weight with water, 812,000 pounds.

Each generator occupies a fore-and-aft distance of eight feet, the two fronts are 112 feet long each, and the passages use 12 feet, making the total of 124 feet, as stated above.

The extreme height of the boilers is 11 feet, leaving a considerable space unused under the deck, which is utilized for ventilation.

Each smoke pipe and its outer pipe is inclosed within iron bulkheads both fore and aft and athwartships. The outside casing of the smoke pipe is large enough to give ample area for a free exit of the heat of the fire rooms, while a supply and circulation is given by fan blowers delivering into the open fire rooms. By an arrangement of the air pipes a suitable number of air jets are directed so as to induce circulation toward and into the ash pits, at the same time creating a cooling current for the benefit of the stokers.

The fans are located on the spar deck in the rooms which inclose the smoke pipes.

She will be equipped with electric signal lights, 100 c.p. each, connected to an automatic alarm attachment located in the pilot house. In case a lamp is extinguished by accident or otherwise, it rings an alarm bell in the pilot house; also lights a lamp, notifying the officers in charge immediately that a lamp has been extinguished.

A refrigerating apparatus will be supplied by the DeLa Vergne Refrigerating Machine Co., of New York.

The *Northwest* has been elegantly fitted up for the accommodation of first-class passengers and for emigrants. She will run between Buffalo and Duluth, and will start from Buffalo on her first trip early in June. She will carry a crew of 142 men, and will stop at Cleveland, Detroit and the Soo. She will run at the rate of twelve miles an hour through the river and twenty miles an hour on the lakes, making the trip from the foot of Lake Erie to the head of Lake Superior in fifty-six hours.

All the boiler material has been subjected to 800 pounds hydrostatic pressure in the rough, and when machined and jointed a final test of 650 pounds—to be absolutely tight at this last test. The boilers will be fitted with the Etna shaking grates. The

fittings, such as valves, cocks, etc., are made especially for the high boiler pressure of the 250 to 300 pounds it is designed to carry.

The electric lighting plant is divided into three units, each unit consisting of a vertical, direct-connected, three-cylinder, triple-expansion engine and dynamo. The units are of 400 sixteen-candle-power light capacity each, and develop an E.M.F. of 110 volts at 300 revolutions per minute. A separate condenser is supplied and connected to the three electric engines, suppressing entirely the noise occasioned by high-pressure exhaust. The engine cylinders are cast in one piece, and supported on eight steel columns, thoroughly braced. The valves are of the piston type, completely balanced. The main crank is cut from a solid forging, and is supported in self-oiling journals lined with gun metal. On one end of the triple-expansion crank is forged a flange, to which is secured the armature shaft. The engines are equipped with automatic relief valves, and thoroughly protected with oil guards.

Vigilancia.—Formerly owned by the Brazil Steamship Company, was recently purchased by the Ward line, and, on her five hours' run to determine her speed under the postal regulations for mail contracts, made an average of $14\frac{7}{8}$ knots.

Kensington.—This is a large twin-screw steamer of about 9,000 tons register, built by J. & G. Thomson, Clydebank, builders of the (City of) *Paris* and *New York*, for the International Navigation Co., and is of interest as embodying some of the most recent features in ship and engine construction. She is built principally for the freight trade between Liverpool and Philadelphia, but has accommodations for 120 first and second-class passengers, and for 1,000 emigrants. She is 480 feet long b. p., 57 feet beam, and forty feet deep, and carries 8,500 tons on a draught of 28 feet; her net tonnage is 5,600. Her rig is the usual fore-and-aft one, there being four pole masts.

The engines are of the quadruple-expansion type with four cranks, the cylinders being $25\frac{1}{2}$, $37\frac{1}{2}$, $52\frac{1}{2}$ and 74 inches diameter by 54-inch stroke, and are designed for 7,000 I.H.P. at 90

revolutions. The boilers work at a pressure of 200 pounds, and are fitted with Serve tubes and induced draft.

Southwark.—A sister ship to the *Kensington*, built by Denny Bros., of the same dimensions, and with engines of the same type and size, the boilers having Serve tubes and working with induced draft. On trial, carrying more than one-half her dead weight capacity (10,000 tons), she made a speed of 16.38 knots on the measured mile.

Normannia.—The following table containing a resumé of the season's work of this ship, shows a remarkably uniform time of passage.

THE NEEDLES TO SANDY HOOK.

Voyage.	Time.	Distance.	Revolutions per minute.		Mean Speed.	Slip, per cent.		Coal per day.
			Port.	*Starb'd.*		*Port.*	*Starb'd.*	
22[1]	6·19·20	3,099	81.75	79.90	18.97	13.94	11.90	301
23	6·16·30	3,116	82.00	80.17	19.41	12 85	11.08	295
24	6 12·30	3,086	82.83	80 70	19.72	12.73	10.50	297
25	6·15·30	3,105	82 44	80.26	19.47	13.37	11.18	297
26[2]	6·16·45	3,062	81 09	78.80	19.05	12.90	11.14	296
27	6·14·0	3,056	81.90	80.20	19.34	12.80	10.80	300
Mean.....	6·15·46	3,087	82.00	80.00	19.33	13.09	11.11	298

SANDY HOOK TO THE NEEDLES.

22	6·20·0	3,128	81.10	79.30	19.07	13.20	11.40	303
23	6·12·30	3,111	83.67	81.44	19.88	12.50	10.16	321
24	6·20 18	3,146	81.64	79 53	19 15	13.52	10.98	322
25	6·12·15	3.060	81.40	79.40	19.58	11.60	9.20	305
26[2]	6·16·5	3,054	80.40	78 60	19.08	12.82	10.60	311
27	6·12·10	3.056	80 70	80 40[4]	19.57	11.50	11.30	320
Mean.....	6·15·33	3,093	81 49	79.78	19.39	12.52	10.61	314
Mean of round trips..	6·15·40	3,090	81.75	79 89	19.36	12.80	10.86	306

1. Port engine stopped four and a half hours.
2. Two and a half hours at half speed.
3. Eight and a half hours with one air pump.
4. Pitch of port screw blades altered.

La Navarre.—This twin-screw vessel, recently completed by the Compagnie Générale Transatlantique, is intended for their West India trade. She is 494 feet long, 49 feet 3 inches beam, 37 feet deep, and displaces 8,922 tons on a mean load draught of 22 feet 8 inches. She is divided into fifteen water-tight compart-

ments by thirteen transverse and one longitudinal bulkhead, the latter between the engines. She has two pole masts and two smoke pipes. Her engines are of the triple-expansion type, with cylinders 31½, 50¼ and 82½ inches diameter by 52½ inches stroke, which, at 90 revolutions per minute, develop 3,750 I.H.P. each. There are four double-ended six-furnace boilers, in two water-tight compartments, each pair in connection with an elliptical smoke pipe 8 feet 10 inches by 5 feet 3 inches. The propellers are 15 feet 4 inches in diameter. She has complete electric light and refrigerating plants, and is fitted up for 250 first-class, 130 second and third-class passengers, and 600 emigrants. Her speed on trial was 18 knots.

YACHTS.

Columbia.—This is the name of the steel steam yacht built by the William Cramp & Sons Ship and Engine Building Co. for J. Harvey Ladew, Esq. The construction of the hull was sublet to the Charles Hillman Company, of Philadelphia, and was launched in August last.

The following are her principal dimensions:

Length over all, feet and inches	191–6
Length on water line, feet	180
Beam, feet	23
Depth, feet	14
Draught of water, feet and inches	10–3
Displacement, tons	400

She has a four-cylinder triple-expansion engine, with cylinders 21½, 31 and two 34 inches in diameter by 20 inches stroke, designed for 1,800 I.H.P., when the engines are running with a piston speed of 800 feet per minute, steam being supplied at 160 pounds pressure by two return-tubular boilers.

Her acceptance trial consisted of a run of 80.52 miles in Long Island Sound, which she did at the rate of 17.85 knots, the average revolutions being 235 per minute and the I.H.P. 1,880. For a distance of 22½ knots she made 18.3 knots.

The engine is a duplicate of those in the *Vesuvius*.

Eleanor.—The Bath Iron Works are building for W. A. Slater, Esq., of Providence, R. I., a bark-rigged steam yacht to cost about $250,000. Her dimensions are:

Length over all, feet	231
Length on water line, feet	208
Beam	32
Depth, feet and inches	17–6
Draught, mean, feet and inches	13–4
Displacement, tons	1,080

Her engine is triple expansion, with cylinders 18, 28 and 45 inches diameter by 30 inches stroke, designed for 1,500 indicated horse power, with which a speed of 16 knots is expected. She will have two return-tubular boilers, working at a pressure of 160 pounds. The screw is four-bladed, 10 feet 3 inches in diameter. The sail area is 14,000 square feet.

Dungeness.—A steel yacht, designed by Mr. George B. Mallory for Mrs. Lucy Carnegie, and built by the Maryland Steel Co., was recently launched at Sparrow's Point. She is 119 feet over all, 101 on the water line, 20 feet beam, 10 feet 3 inches deep, and displaces 191 tons on a mean draught of 6 feet 6 inches.

The motive power comprises a single-screw compound engine and a Scotch boiler, together with the usual auxiliaries. The engine has cylinders 13 and 24 inches diameter by 18 inches stroke, and has been designed to develop about 200 horse power with natural draft when the engines are making 180 revolutions per minute. The main boiler is 10 feet 6 inches diameter and 10 feet long, with two furnaces 38 inches diameter. The grate surface is 38 square feet, and the working pressure 125 pounds. There is also a small donkey boiler for use in port.

She has been fitted up in the most approved style, and will be ready for her trial in a short time.

Rona.—On the 12th of December Messrs. D. & W. Henderson, the builders of the *Valkyrie*, launched from their yard at Partick, Glasgow, a large steam yacht, built from the design of Mr. G. L. Watson for Mr. A. H. E. Wood, of Rugby. The "Marine Engineer" gives the following particulars of her:

"The vessel is of handsome model and exceptional dimensions. The length over all is about 270 feet; beam, 30 feet 3 inches; depth, 19 feet 8 inches. The Thames measurement tonnage will be about 1,000. She has been built under Lloyd's special survey, and is classed in their yacht register 100 A1. The arrangements for the accommodation of the owner and his friends are of the most complete description, everything that can add in the least degree to their comfort having been included in the yacht's design. There is a great height in 'tween decks—nearly 9 feet—which is

of advantage in the state rooms and saloons. The state rooms are eleven in number and are of large size. They have a polished walnut dado with figured cretonne above. The five larger state rooms have baths under the floors, supplied with hot and cold water. A complete system of electric bells is fitted throughout the rooms. Immediately forward of the machinery space is the pantry, which is complete with all the usual dressers, racks, &c. It communicates with the galley above by means of a hoist, and with the saloon by a serving window. The dining saloon is a handsome apartment, well lighted by a large dome skylight filled with stained glass. Aft of the engine space is the boudoir, which is fitted with a handsome fireplace, piano, &c. The cabinet work of both these apartments is from designs by Mr. T. L. Watson, F. R. I. B. A., and will be of the most artistic description.

"The accommodation for the officers and engineers comprise a mess room and pantry, seven rooms, bath, &c. The crew are berthed forward in a large forecastle, which is complete with berths, seats, lockers, &c. The firemen's berths are amidships, and are entered off the engine room. A bath is also fitted for their use. On the upper deck is a teak-paneled house, containing the drying room, chart room, galley, photographic dark room, scullery and the companion house to main saloon. This latter is a handsomely finished apartment, containing lounges, chairs, writing table, piano, &c. In side-houses amidships are the boot room, larder, ice chest, cloak room, &c. Electric light will be fitted throughout the vessel. The heating and ventilation of the cabins, to suit the varying climates to which the vessel will be exposed, have received special attention. The ventilation is effected by the ordinary method, and also by electric fans. These draw air through a system of conduits so arranged that any room can be shut off at will. The heating of the rooms is done by a complete system of hot-water piping. For provisioning for long voyages there is a refrigerating chamber and machine. A large number of boats will be carried, including steam and electric launches and two one-rating yachts. The vessel will be rigged as a two-masted schooner, with square sails on the foremast. The builders' firm have also made the machinery. The engines

are of the triple-expansion type, with cylinders 23 inches, 38 inches and 64 inches by 36 inches stroke. With these it is expected that the vessel will develop a high rate of speed."

Valiant.—Mr. Vanderbilt's new yacht, described in the last number of the JOURNAL, recently made the run from New York to Gibraltar in 9 days and 9 hours, or at the rate of about 15 knots an hour.

BOOK REVIEWS.

PROCEEDINGS OF THE DIVISION OF MARINE AND NAVAL ENGINEERING AND NAVAL ARCHITECTURE OF THE INTERNATIONAL ENGINEERING CONGRESS.

The readers of the JOURNAL have already been given some idea of the work of this Congress, held at Chicago last summer in connection with the Columbian Exposition, by the brief account published in the August number. In the advertising pages it was announced that the Proceedings would be issued in December, and they appeared at the end of that month.

Engineer-in-Chief Melville is the responsible editor of the two handsome volumes, but the details of this laborious work were carried out under his immediate supervision by Passed Assistant Engineer W. M. McFarland, U. S. N., whose duties as editor of the JOURNAL for the past two years gave him excellent training for the task.

Dr. Francis Elgar, the distinguished English naval architect, who was an active member of the Congress, said at its close: "I venture to predict that the Proceedings of this Congress will form, in the future, one of the most valuable works upon naval architecture and marine engineering that have ever been published," and in this opinion we heartily concur after a careful study of the two volumes.

In planning the list of subjects, Engineer-in-Chief Melville aimed to have every live topic in marine engineering and naval architecture treated by a leader of the profession who had devoted special attention to his subject, and his success is remarkable. Sir Nathaniel Barnaby has treated Warship Design; Dr.

Elgar, Naval Architecture; Mr. Howden, Forced Draft; Mr. E. S. Cramp, Steel Castings for Marine Machinery; Col. Soliani, Liquid Fuel for War Vessels; Mr. Seaton, Multiple-Expansion Engines; Mr. Sydney Barnaby, Screw Propellers; Mr. Charles Ward, Coil Boilers; Mr. Geo. W. Dickie, Auxiliary Machinery for Naval Vessels; Mr. Nelson Foley, Boiler Construction, and so on. In all, there are forty-three authors, and nothing but such an international occasion could have brought out so many valuable papers by authors of such eminence.

Space will not permit a detailed notice of the work, as its scope is so vast, but we may remark that no naval architect or marine engineer who pretends to keep posted on the latest development of his profession can afford to be without it. Besides the papers themselves, the discussions are of great value, and the illustrations are unusually numerous and helpful. The papers on liquid fuel, hydraulic machinery, auxiliary machinery for naval vessels, and steamers of the Great Lakes are illustrated so fully that nothing is omitted.

A feature which has been worked out with great care is the index, which of itself covers nearly twenty pages. An effort has been made to render the treasures of the book readily accessible, and we believe it has been successful in a degree never before reached in a technical work. The references are not merely by titles and authors' names, but every valuable item in the body of an article is given with cross references when needed.

The publishers are Messrs. John Wiley & Sons, the well-known New York firm, and, besides praise for their share of the work in the ordinary sense, they deserve the thanks of the profession for their public spirit in taking the financial risk involved. When they agreed to publish the work not half of the papers had been received, so that it was their pride as American publishers and engineers that led them to take the risk, without knowing what would be the cost. The actual cost has been nearly double the estimated. Thus, in addition to the intrinsic merit of the work, it should commend itself to all American engineers and naval architects who desire that the patriotism of the publishers shall be appreciated.

DIE TECHNISCHE ENTWICKLUNG DES NORDDEUTSCHEN-LLOYDS UND DER HAMBURG-AMERIKANISCHEN PACKETFAHRT-AKTIENGESELLSCHAFT.—BY R. HAACK AND C. BUSLEY. BERLIN: JULIUS SPRINGER, 1893.

This quarto volume of 236 pages gives the history of these two steamship lines, with lithographic plates of the ships and of their machinery, together with indicator diagrams from the different types of engines illustrated. The eighteen ship plates give, to scale, a longitudinal section, deck plans and cross-sections of the typical vessels described, including such as the *Augusta Victoria*, the *Fürst Bismarck*, the *Kaiser Wilhelm II* and the *Havel*, while the text contains illustrations and full descriptions of all the ships of both fleets. The sixteen machinery plates give a longitudinal section, plan and end view of the engines, longitudinal and cross-sections of the boilers, and a drawing of the screws. They include the triple-expansion engines of the *Fürst Bismarck*, the *Normannia*, the *Lahn* and the *Spree*, and the quadruple-expansion engines of the *Kronprinz Friedrich Wilhelm*, together with many others of an earlier date. That part of the text pertaining to the machinery contains complete data of the machinery of all the vessels, and is profusely illustrated; and as the two fleets were built in many yards, a good insight is given into the practice of such establishments as Fairfield, Laird's, Vulcan Works and Denny's.

Although there is much in the work that is of interest chiefly from an historical standpoint, the data and plans of the modern ships and machinery are of such a character as to make it one of much value to ship and engine builders and designers.

ANNUAL MEETING.

The *Annual Meeting* of the Society was held December 22, 1893, in the office of the Engineer-in-Chief of the Navy.

After a short address by the President, reviewing the growth of the Society, the election of officers was held, resulting as follows:

President: Chief Engineer H. Webster, U. S. N.

Secretary-Treasurer: Passed Assistant Engineer R. S. Griffin, U. S. N.

Members of Council, in addition to the President and the Secretary:

Passed Assistant Engineer F. H. Bailey, U. S. N.; Passed Assistant Engineer B. C. Bryan, U. S. N.; Assistant Naval Constructor F. W. Hibbs, U. S. N.

The report of the Secretary-Treasurer was then read, showing the financial condition of the Society to be excellent. It is as follows:

WASHINGTON, D. C., *December* 22, 1893.

To the American Society of Naval Engineers:

Gentlemen: In accordance with the requirements of section 14 of the By-Laws, I have the honor to submit the following report of the finances of the Society for the year ending to-day:

Balance on hand December 22, 1892	$1,148 26
Received for annual dues	2,207 75
" for subscriptions, reprints and extra copies	624 00
" for advertising	1,289 39
" for interest on deposits	30 84
Total receipts	$5,300 24
Expended for printing JOURNAL	$2,311 60
" for illustrations	511 46
" stationery, postage and incidentals	151 30
" International Engineering Congress	135 80
" salary of Secretary-Treasurer	600 00
Total expenditures	$3,710 16
Balance on hand December 22, 1893	$1,590 08

All of which is respectfully submitted.

WALTER M. MCFARLAND,
Passed Assistant Engineer, U. S. N.,
Secretary-Treasurer.

Passed Assistant Engineer B. C. Bryan, U. S. N., then read a paper on Turning Efforts on Crank Shafts of High-Speed Engines, and Passed Assistant Engineer F. H. Bailey, U. S. N., one on Steam Cylinders of Air-Pump Engines, both of which will be published in the JOURNAL.

After a vote of thanks to the retiring Secretary-Treasurer for his able and successful management of the office, the meeting adjourned.

The report of the Secretary-Treasurer has since been audited and found to be correct.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

OFFICERS FOR 1894.

President:
Chief Engineer **H. Webster**, U. S. Navy.

Secretary and Treasurer:
Passed Assistant Engineer **R. S. Griffin**, U. S. Navy.

Librarian:
Passed Assistant Engineer **W. W. White**, U. S. Navy.

Council:
Chief Engineer **H. Webster**, U. S. Navy.
Passed Assistant Engineer **R. S. Griffin**, U. S. Navy.
Passed Assistant Engineer **Frank H. Bailey**, U. S. Navy.
Passed Assistant Engineer **B. C. Bryan**, U. S. Navy.
Assistant Naval Constructor **F. W. Hibbs**, U. S. Navy.

HONORARY MEMBERS.

(EX-OFFICIO.)

The Secretary of the Navy.

The Assistant Secretary of the Navy.

Chief of Bureau of Steam Engineering:
Geo. W. Melville, Engineer-in-Chief, U. S. N., Navy Department.

Ex-Chiefs of Bureau of Steam Engineering:
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American Engineer and Railroad Journal.....47 Cedar street, New York.
American Machinist.....168 Fulton street, New York.
American Shipbuilder.....7 Coenties Slip, New York.
American Society of Mechanical Engineers.....12 West 31st street, New York.
Army and Navy Journal.....240 Broadway, New York.
Army and Navy Register.....National Theater Building, Washington, D. C.

Canadian Military Gazette.....P. O. Box 387, Montreal, Canada.
Cassier's Magazine.....Potter Building, New York.

Engineering.....35 Bedford street, Strand, London, England.
Engineer (The).....150 Nassau street, New York.
Engineering Magazine.....No. 47, Times Building, New York

Forest and Stream.....318 Broadway, New York.
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Journal of the United States Artillery.....Fort Monroe, Va.

Marine Journal.....132 Nassau street, New York.
Marine Record.....144 Superior street, Cleveland, Ohio.
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"Mechanics".....430 Walnut street, Philadelphia, Pa.

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"Power".....World Building, New York.

"Seaboard".....19 Barclay street, New York.
Stevens Indicator.....Stevens Institute, Hoboken, N. J.

United Service.....1510 Chestnut street, Philadelphia, Pa.

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